Assessment of Renewable Energy and Conservation Opportunities for Ministry of Transportation and Communications Remote Facilities

Final Report

Ontario
Ministry
of
Energy

Honourable
George Ashe
Minister

Energy
Ontario

ASSESSMENT OF RENEWABLE ENERGY
and
CONSERVATION OPPORTUNITIES FOR
MINISTRY OF TRANSPORTATION
AND COMMUNICATIONS
REMOTE FACILITIES
Final Report

Prepared for

Ontario Ministry of Energy

By

Marbek Resource Consultants Ltd.

June, 1984

Page

EXECUTIVE SUMMARY

CONTENTS

INTRODUCTION 1

1.1 Background 1
1.2 Study Objectives 2
1.3 Structure of Report 2

PART A STUDY OVERVIEW 5

2.1 Study Approach 6
  2.1.1 Preliminary Inventory 7
  2.1.2 Site Visits and Energy Audits 8
  2.1.3 Phase I Report 11
  2.1.4 Phase II 12
  2.1.5 Field Consultations 12
  2.1.6 Prefeasibility Studies 13
  2.1.7 Final Report 13

2.2 Inventory of Remote MTC Facilities 14

  2.2.1 Introduction 14
  2.2.2 Airport Buildings 14
  2.2.3 Airport Power Systems 18
  2.2.4 Dedicated Power Systems for Communications Facilities 20

2.3 Current Fuel Consumption and Costs 26

  2.3.1 Airport Facilities 26
  2.3.2 Communications Facilities 29

Page

2.3.3 Total Annual Costs - MTC Airport and Communications Facilities 31

2.4 Overview of Potential Savings 32

2.4.1 Airport Facilities 32
2.4.2 Communications Facilities 34

2.5 Overview of Study Recommendations 37

PART B MTC REMOTE AIRPORT FACILITIES 41

BUILDINGS AND POWER SYSTEMS AT EXISTING AIRPORTS 42

3.1 Introduction 42

3.2 Existing Airport Houses 44

3.2.1 Description 44
3.2.2 Current Fuel Consumption and Costs 45
3.2.3 Retrofit Measures 47
3.2.4 Estimated Retrofit Costs and Savings 52
3.2.5 Recommended Action 55

3.3 Existing Airport Garages 56

3.3.1 Description 56
3.3.2 Current Fuel Consumption and Costs 57
3.3.3 Retrofit Measures 60
3.3.4 Estimated Retrofit Costs and Savings 67
3.3.5 Recommended Action 68

Page

3.4 Existing Airport Waiting Rooms 69

3.4.1 Description 69
3.4.2 Current Fuel Consumption and Costs 69
3.4.3 Retrofit Measures 71
3.4.4 Estimation of Retrofit Costs and Savings 71
3.4.5 Recommended Action 71

3.5 Existing Airport Power Systems 72

3.5.1 Description 72
3.5.2 Current Fuel Consumption and Costs 73
3.5.3 Retrofit Measures 74
3.5.4 Estimated Retrofit Savings and Costs 76
3.5.5 Recommended Action 87

NEW MTC REMOTE AIRPORT FACILITIES

4.1 Introduction 89

4.2 New Houses for MTC Remote Airports 90

4.2.1 Background 90
4.2.2 Upgraded Version of Lansdowne House Airport House Design 91
4.2.3 Super Energy Efficient Remote Airport House Design 95

4.3 New Garages for MTC Remote Airports 101

4.3.1 Background 101
4.3.2 Energy Efficient Features for New Garages 103
4.3.3 Estimated Energy Consumption and Costs 106
4.3.4 Recommended Actions 110

Page

4.4 New Waiting Rooms for MTC Remote Airports 111

4.4.1 Background 111
4.4.2 Energy Efficient Features of New Waiting Rooms 111
4.4.3 Estimated Costs and Savings 112
4.4.4 Recommended Action 114

WINISK AIRPORT FACILITIES

5.1 Introduction 115

5.2 Winisk Airport Hotel 116

5.2.1 Description 116
5.2.2 Current Fuel Consumption and Costs 117
5.2.3 Retrofit Measures 117
5.2.4 Estimated Retrofit Costs and Savings 120
5.2.5 Recommended Action 124

5.3 Winisk Airport Manager's House 126

5.3.1 Description 126
5.3.2 Current Fuel Consumption and Costs 126
5.3.3 Retrofit Measures 127
5.3.4 Estimated Costs and Savings 129
5.3.5 Recommended Action 129

5.4 Winisk Airport Waiting Room 130

5.4.1 Description 130
5.4.2 Current Fuel Consumption and Costs 130
5.4.3 Retrofit Measures 132
5.4.4 Recommended Action 133

Page

5.5 Winisk Power System 134

5.5.1 Description 134
5.5.2 Current Fuel Consumption 135
5.5.3 Retrofit Wind Turbine Generator 139
5.5.4 Estimation of Potential Wind Energy Contribution 142
5.5.5. Estimated Costs and Savings 145
5.5.6 Recommended Action 149

PART C MTC REMOTE COMMUNICATIONS POWER SYSTEMS 150

INTERMITTENT CHARGE DIESEL GENERATING SETS FOR MTC REMOTE COMMUNICATIONS SITES 151

6.1 Introduction 151

6.2 Current Fuel Consumption and Costs 156

6.2.1 Slate Falls 156
6.2.2 Bearskin Lake 157
6.2.3 Sachigo Lake 158
6.2.4 Bell Canada Estimates of Fuel and Maintenance Costs 159

6.3 Intermittent Charge Diesel Option: An Overview 161

6.4 System Specifications 164

6.4.1 System Size 164
6.4.2 Power Supply 167
6.4.3 Battery Requirements 167
6.4.4. Building Heating System 168

Page

6.4.5 Exchange/Satellite Building Modifications 169
6.4.6 Control System 170

6.5 Estimation of Fuel Consumption and Engine Run time 172

6.6 Economic Analysis 175

6.6.1 Annual Operating Costs 175
6.6.2 Capital Cost 179
6.6.3 Cost Summary 180

6.7 Recommended Action 183

USE OF PHOTOVOLTAICS TO REDUCE FUEL CONSUMPTION IN INTERMITTENT CHARGE DIESEL GENERATING SYSTEMS FOR REMOTE COMMUNICATIONS FACILITIES 185

7.1 Introduction 185

7.2 Calculation of Fuel Savings 186

7.2.1 Solar Radiation Available 187
7.2.2 Potential for Energy Savings 188
7.2.3 Optimum Array Size 188

7.3 Sample Calculation of Monthly and Annual Fuel Savings for a Typical Microwave Exchange Site. 190

7.3.1 Base Load 190
7.3.2 Size of Array 191
7.3.3 Monthly/Annual Energy Savings 191
7.3.4 Monthly/Annual Fuel Savings 191

Page

7.4 Cost Effectiveness 194

7.5 Recommended Action 196

EXECUTIVE SUMMARY

INTRODUCTION

This is the final report of a study carried out on behalf of the Ontario Ministry of Energy (MOE) and the Ministry of Transportation and Communications (MTC). The study is entitled:

> Assessment of Renewable Energy and Conservation Opportunities for Ministry of Transportation and Communications Remote Facilities

OBJECTIVE

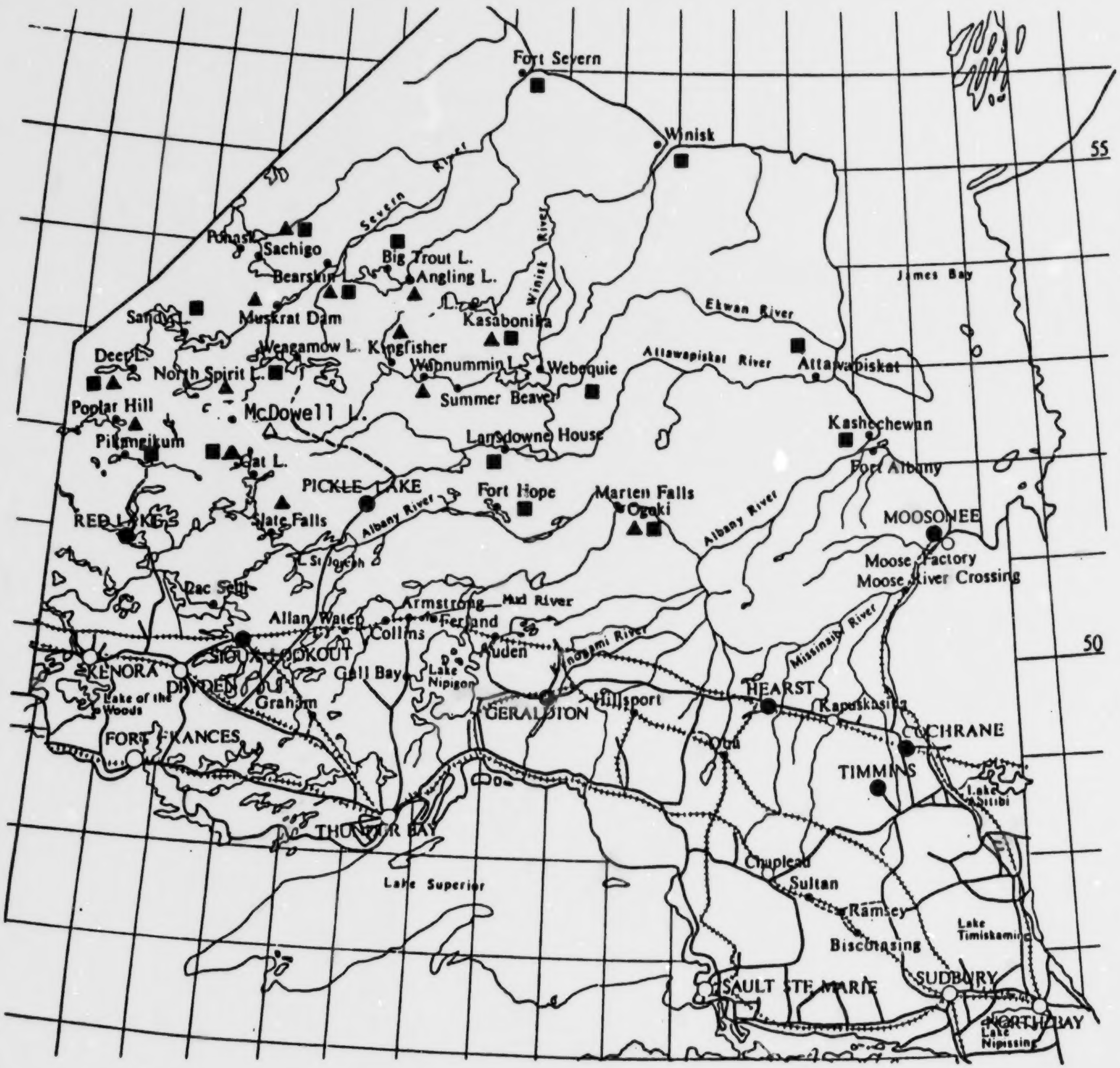
The overall objective of this study is:

> "to undertake energy audits on specific MTC facilities in Northern Ontario remote communities, and to identify specific energy conservation measures as well as renewable and alternative energy technologies which can reduce building and equipment energy requirements and maintenance costs in these facilities."

FACILITIES ASSESSED

The study assessed 16 MTC remote airports and 16 remote Telesat and microwave communications sites that serve Northern Ontario communities without Ontario Hydro community power. Fourteen (14) of the communications sites are powered by MTC dedicated diesel sets. Two sites (Winisk and Fort Severn) receive power from Ontario Northland Transportation Commission (ONTC) diesel sets which also provide power to other local government facilities. Map #1 shows the location of both the airport and communications facilities.

Actual site inspections and energy audits were conducted at:


Fort Severn
Winisk
55
50
Severn River
Winisk River
Ekwan River
Attawapiskat River
Albany River
Mud River
Missinaibi River
Kenogami River
James Bay
Lake Superior
Lake Nipigon
Lake of the Woods
Lake Abitibi
Lake Timiskaming
Lake Nipissing
Poplar Hill
Pikangikum
Deer L.
Sandy L.
North Spirit L.
McDowell L.
Cat L.
Pickle Lake
Red Lake
Slate Falls
L. St. Joseph
Bearskin
Sachigo
Muskrat Dam
Weagamow L.
Kingfisher
Big Trout L.
Angling L.
Kasabonika
Wunnummin L.
Webequie
Summer Beaver
Lansdowne House
Fort Hope
Marten Falls
Ogoki
Attawapiskat
Kashechewan
Fort Albany
MOOSONEE
Moose Factory
Moose River Crossing
Armstrong
Ferland
Collins
Allan Water
Auden
Gull Bay
Sioux Lookout
Dryden
Kenora
Graham
Fort Frances
Thunder Bay
Geraldton
Hillsport
Hearst
Kapuskasing
Cochrane
Timmins
Chapleau
Sultan
Ramsey
Biscotasing
Sault Ste Marie
Sudbury
North Bay

MAP 1

MAP OF MTC REMOTE FACILITIES IN NORTHERN ONTARIO

Communities with MTC Airports	■
Communities with MTC Dedicated Communications Power Systems	▲
Supply Centres	●
Other Major Centres	○
Highways	———
Gravel or seasonal road	- - - - -
Railways	┼┼┼┼┼┼

SCALE 1:4 000 000

mi 50 100

km 100 200

- Airport Facilities - Bearskin Lake, Big Trout Lake, Sachigo Lake, Winisk
- Communications Facilities - Slate Falls, Bearskin Lake, Sachigo Lake

Data on the remaining MTC remote sites were obtained through extensive consultations with regional office staff of MTC, Bell Canada, Ontario Northland Transportation Commission (ONTC) and Telsat Canada and through review of Bell Canada, ONTC and MTC records.

CURRENT OPERATING COSTS

This report identifies current annual fuel and maintenance costs for the space heating of airport buildings and the operation of airport diesel generators as well as annual fuel and maintenance costs for the operation of diesel generator sets at MTC communications facilities. As shown in Table 1, these annual costs were approximately $1 million in 1983/84.

TECHNICAL OPTIONS ASSESSED

The study assessed five specific sets of technical options:

- Energy conservation retrofit measures for buildings and power systems at existing MTC airports (excluding Winisk)
- Innovative designs for energy efficient buildings and power systems for new MTC airports
- Energy conservation retrofit measures for buildings and wind energy retrofit for the power system at Winisk airport
- Intermittent charge diesel generator sets for MTC remote communications facilities
- Use of photovoltaics as a "fuel saver" with an intermittent charge diesel system at MTC remote communications facilities.

TABLE 1

SUMMARY OF ANNUAL FUEL AND DIESEL MAINTENANCE COSTS IN MTC REMOTE FACILITIES

Function	Annual Cost (1983)	% of Total
A. Airports-Heating		
1. Houses	$ 62,430	6%
2. Garages	155,740	15%
3. Waiting Rooms	38,530	4%
(sub total)	($256,700)	(25%)
B. Airports - Power		
4. Fuel	$ 199,740	20%
5. Maintenance	$ 85,000	8%
(sub total)	($ 284,700)	(28%)
C. Communications		
6. Fuel	$ 159,340	16%
7. Maintenance	$ 308,000	31%
(sub total)	($ 467,340)	(47%)
TOTAL	$1,008,779	100%

POTENTIAL SAVINGS

The total annual savings resulting from implementation of the measures recommended within the report are estimated to be in excess of $385,000. The total capital investment required is about $1 million. A summary is presented below.

Existing Airport Buildings: As shown in Table 2, the current annual fuel consumption for all MTC remote airport facilities (381,000 litres) can be reduced to about 153,000 litres through implementation of the recommended energy retrofit measures. This represents a 60% fuel reduction and an annual savings of about $150,000 (1983 fuel prices). The required capital investment is estimated to be approximately $116,000. The simple payback period is less than one year.

New Airport Buildings: Specifications for the design and layout of new airport buildings are presented. In comparison to current designs the estimated annual fuel and cost savings are:

- new houses - 40% reduction
- new garages - 70% reduction
- new waiting rooms - 80% reduction

The required incremental capital requirement is about $5,000 for a house, $3,200 for the garage and $1,000 for a waiting room. The corresponding simple payback periods are: house - 6.7 years; garage - 6 months and; waiting room - 7 months.

Airport Power Systems: Specifications are provided for utilizing waste heat from the airport diesel generator for space heating in the airport garage. Two alternative system designs are presented: depending on the specific application, up to 100% of the garage's space heating requirements could be met by the diesel waste heat.

TABLE 2

MTC REMOTE AIRPORT FACILITIES
POTENTIAL FUEL AND COST SAVINGS
- Airport Buildings

Building	Fuel Consumption (litres)			Annual Fuel Cost *			Capital Expenditure Required**	Simple Payb Period
	Current	Post Retrofit	Savings	Current	Post Retrofit	Savings		
Houses	95,400	44,050	51,350	$ 62,428	$ 30,691	$ 31,837	$ 54,600	1.7 yr.
Garages	230,800	89,100	141,700	$155,736	$ 61,018	$ 94,718	$ 40,150	6 months
Waiting Rooms	55,000	20,100	34,900	$ 38,535	$ 14,517	$ 24,018	$ 21,325	11 months
TOTAL:	381,200	153,250	227,950	$245,599	$106,126	$150,573	$116,075	

* 1983 unit prices

** 1984 dollars

Communications Facilities: As shown in Table 3, the current overall fuel and maintenance costs ($33,400) for operating diesel generating sets at a remote communications site can be reduced to approximately $14,400 at an exchange site and $9,920 at a satellite/toll station. This represents an annual savings of $19,000 per exchange site and $23,480 per satellite/toll station. The required capital expenditure is estimated to be about $88,000 per site. The simple payback period is 4.6 years for an exchange site and 3.7 years for a toll station.

Eleven (11) potential sites are identified where installation of an intermittent charge system appears to be practical. The net present value of savings, resulting from replacement of the current conventional diesel sets with intermittent charge systems is estimated to be $3.1 million.

STUDY CONCLUSIONS AND RECOMMENDATIONS

Existing Airport Buildings: The recommended package of energy retrofit measures for existing airport buildings-house, garage and waiting room - provides significant fuel and cost savings as well as a very short payback period. Therefore,

Recommendation #1: It is recommended that MTC establish an Airport Building Retrofit Program. Given the scope of the recommended measures, it is recommended that 3-5 airports be retrofitted each year. Retrofit actions should be planned for the normal construction period. All airport facilities would therefore be retrofitted within a 3-5 year period.

New Airport Facilities: The design specifications presented for new airport buildings provide significant and cost-effective fuel savings. Therefore,

TABLE 3

MTC REMOTE COMMUNICATIONS FACILITIES
POTENTIAL FUEL/MAINTENANCE COST SAVINGS
- Per Site

Installation	Annual Average Costs -Fuel and Maintenance Costs		Potential Savings/Site	Capital Expenditure Required/Site	Simple Payback
	Current	Cycle Charge 2000			
Exchange Site	$ 33,400	$ 14,200	$ 19,200	$ 87,700	4.6 years
Toll Station	$ 33,400	$ 9,800	$ 23,600	$ 87,700	3.7 years

Recommendation #2: It is recommended that new airport buildings be constructed in accordance with the design specifications presented. It is also recommended that MTC initiate two or three information and training sessions on energy efficient construction techniques for its construction supervisors and/or regular contractors.

Airport Power Systems: The current MTC practice is to install a "temporary" construction diesel-generator at new airport sites with the expectation that they will shortly be replaced by community power. In actual practice these "temporary" installations often remain in operation for 5-10 years before community power is available to the airport. As a result of this current installation method, fuel and maintenance costs are very high and waste heat cannot be utilized for airport building heating. The additional cost of a proper "permanent" installtion with heat recovery would be easily recouped through savings in fuel, maintenance and heating costs. Therefore,

Recommendation #3: It is recommended that "permanent" 15KW generator sets with heat recovery be installed at Cat Lake, Ogoki and future new MTC remote airports.

Recommendation #4: It is recommended that a permanent 50KW dual diesel system, with heat recovery be installed at Bearskin Lake, where community power will never be available to the airport. The Bearskin installation could use at least one of the present 50KW engines at Fort Severn when that community receives community power in 1984/85.

Winisk Airport Facilities: The facilities at Winisk are unique and are therefore considered separately in the report. Assessment of energy conservation options for the airport buildings showed significant potential for fuel savings. The airport also has 3 x 50kW diesel generators. The report assessed the technical and economic feasibility of utilizing a wind/diesel hybrid system to reduce power generating costs. While the DAF Indal 50 kW VAWT has a proven technical performance in remote settings, its installation at the Winisk airport is not cost-effective. A smaller turbine, the 16kW Northwind L-916 HAWT, proved to be cost-effective but has not yet been tested in a severe remote climate. Stand-alone wind turbine systems for use with diesel generators sets are not yet commercially available. Therefore,

Recommendation #5: It is recommended that the Ministry of Energy continue to monitor the development and demonstration of the Northwind L-916 and/or other induction wind turbines in the 15-30KW range, and stand-alone synchronous systems in the 50 to 80kW range. Once their technical reliability in a severe, remote setting is established, the installation of a wind/diesel hybrid system at Winisk should be reassessed.

Communications Facilities: The report concludes that intermittent charge diesel sets, such as the Mechron Energy Ltd. series 2000 system, present a very attractive option for achieving significant fuel and maintenance cost savings at remote communication sites. The report also shows that a PV array can provide further fuel savings when used in conjuction with the Mechron "cycle-charge" diesel system. However, the present cost of PV modules ($10/peak watt) doesn't provide an attractive payback. However, PV module costs are expected to continue to decline; at about $3.70/peak watt, PV will be cost competitive for use with an intermittent charge diesel system at a remote communications site. The small communications load (80 watts) at Angling Lake, makes this site particularly attractive for a PV demonstration. The report notes that one demonstration of the Mechron "cycle charge" series 2000 system is already planned for a Bell Canada repeater site. Therefore,

Recommendation #6:	It is recommended that, subject to favourable demonstration results, further applications of the Mechron "cycle-charge" series 2000 system be encouraged leading to the possible gradual replacement of all existing conventional diesel sets at MTC remote communications sites.
Recommendation #7:	It is recommended that, if and when, the current diesel generating sets are replaced at Angling Lake by the "cycle charge" system, the Ministry of Energy should consider incorporating the installation of a demonstration PV array.

SECTION I

INTRODUCTION

1.1 BACKGROUND

The Ministry of Transportation and Communications (MTC) owns and maintains 16 airports that serve remote Northern Ontario communities. One additional airport is in the process of being constructed at Cat Lake. All airport buildings use oil for heating, and in 8 locations where community power is not available, MTC provides its own diesel generated power at the airport.

MTC also provides power to 16 Telsat and microwave communications facilities that serve remote Northern Ontario communities without Ontario Hydro community power. Two of these communications facilities are operated by the Ontario Northland Transportation Commission (ONTC), the other 14 are operated by Bell Canada. In all cases, power is provided using diesel generators.

The cost of fuel oil used for heating and power generation in Northern Ontario remote communities is one of the highest in the world. All fuel must be flown in. Current MTC prices for fuel oil range from 62¢ to $1.15 per litre; Ontario Hydro electricity rates for commercial/institutional users are approximately 50¢/kWh. Maintenance costs are also high, because of the severe climate and the need to fly in replacement parts and maintenance crews.

As a consequence of the high fuel and maintenance costs for both airports and communications facilities, the Ontario Ministry of Energy in conjunction with MTC has contracted with Marbek Resource Consultants Ltd. to undertake an assessment of the opportunities for reducing operating costs in MTC's remote facilities.

1.2 OBJECTIVE

The overall objective of this study is:

> "to undertake energy audits on specific MTC facilities in Northern Ontario remote communities, and to identify specific energy conservation measures as well as renewable and alternative energy technologies which can reduce building and equipment energy requirements and maintenance costs in these facilities."

1.3 STRUCTURE OF THIS REPORT

This is the Final Report and therefore presents a complete account of all work carried out within the study. The study's findings are presented in three (3) Parts:

- Part A - Study Overview
- Part B - MTC Remote Airport Facilities
- Part C - MTC Remote Communicatins Facilities

In Part A, the study's approach is outlined and an overview is presented of:

- MTC's remote airport and communications facilities
- current annual fuel and maintenance costs
- potential savings
- study conclusions and recommendations.

Part B presents a comprehensive assessment of fuel and maintenance cost saving opportunities in MTC remote airport facilities. Discussion of the opportunities includes detailed technical and economic assessments as well as recommended actions. Part B is presented in three sections:

- Section 3: Buildings and Power Systems at Existing MTC Airports (excluding Winisk)
- Section 4: Buildings and Power Systems for New MTC Airports (excluding Winisk)
- Section 5: Buildings and Power Systems at Winisk Airport

Part C presents a comprehensive assessment of fuel and maintenance savings opportunities in MTC remote communications facilities. As in Part B, discussion of the opportunities includes a detailed technical and economic assessment as well as recommended actions.

Part C is presented in two sections:

- Section 6: Intermittent Charge Diesel Generator Sets for MTC Remote Communications Facilities
- Section 7: Use of Photovoltaics to Reduce Fuel Consumption in Intermittent Charge Diesel Generating Systems for MTC Remote Communications Facilities.

PART A

STUDY OVERVIEW

INTRODUCTION

Part A outlines the Study's approach and provides an overview of:

- MTC remote airport and communications facilities
- Current fuel consumption and costs
- Potential savings
- Study conclusions and recommendations

SECTION 2
STUDY OVERVIEW

2.1 STUDY APPROACH

The study was undertaken in two phases.

Phase I of the study consisted of the following steps:

- preparation of a preliminary inventory of MTC remote facilities
- site-visits and energy audits at selected "typical" remote MTC facilities
- preparation of Phase I report containing inventories and energy audit results.

Phase II of the study consisted of the following additional steps:

- identification of technical options for reducing energy consumption and costs at the MTC remote sites
- further field consultations
- prefeasibility studies on selected energy conserving options
- preparation of the Final Report

Each step is described below.

2.1.1 Preliminary Inventory

Existing data contained in previous reports were reviewed and contacts were established with senior personnel within the northern regional offices of the Ministry of Transportation and Communications and Bell Canada. On the basis of the data review and personal contacts, two separate questionnaires were prepared and sent to appropriate personnel for completion. The first questionnaire was sent to the MTC regional office in Thunder Bay and sought information pertaining to current remote airport facilities. Information gathered for each airport facility included:

- building descriptions (age, construction type, size)
- current annual fuel consumption
- site fuel costs
- diesel electricity systems and annual fuel and maintenance costs
- electrical loads

The second questionnaire was sent to the Bell Canada regional office, also in Thunder Bay and sought data pertaining to the current operation of remote communications sites. Information gathered for each communications site included:

- specifications on installed diesel electricity generating sets
- annual fuel consumption and costs
- recurring maintenance problems and annual costs
- current and projected electrical loads

Based on the data gathered, a preliminary inventory for both airport and communications sites was prepared. Following presentation of this data to the client, discussions were held and sites were selected for site-visits and energy audits.

2.1.2 Site Visits and Energy Audits

In consultation with Ministry of Transportation and Communications and Ministry of Energy personnel the following MTC facilities were selected for detailed study and an energy audit:

- Bearskin Lake airport buildings and power generator
- Slate Falls Telsat communications power generator
- Winisk airport buildings and power generators.

Site visits to these facilities were made in January 1984. At the same time, brief site visits were made to the following facilities to investigate any variations between buildings of different ages and between the loads from satellite and microwave communications equipment:

- Big Trout Lake airport buildings
- Sachigo airport buildings and power generator
- Bearskin Lake microwave communications power generator
- Sachigo Lake Telesat communications power generator

Bearskin Lake airport was selected for an energy audit because the buildings are typical of those found at 13 other airports and because it is one of the only airports that is likely to have a permanent need for its own power generator. (The airport is situated 8 km. from the community.)

Slate Falls Telsat communications power generator was selected for an energy audit because it is likely to have a permanent need for its own power generator (there are no plans for community power in Slate Falls.), and because it is a prospective demonstration site for intermittent charge diesel generating equipment. (There is convenient air access to the site from Pickle Lake.)

Winisk airport buildings and power generators were selected for an energy audit because of the unique design of the facilities, and the high annual fuel costs.

Big Trout Lake airport was selected for a site check because its buildings were some of the first constructed in the area and would provide a check on building construction variations over the 1975 to 1979 period.

Sachigo airport was selected for a site check because its buildings were constructed more recently than Bearskin Lake and because it currently has its own power generator. The visit provided a check on recent building variations and on the electrical load for an airport.

The Bearskin Lake microwave communications generator was selected for a site check because it powers a microwave exchange system. The Sachigo Lake Telsat communications generator was selected for a site check because it powers a satellite exchange system.

Table 2.1 contains a complete list of the facilities visited.

TABLE 2.1

SITE VISITS TO MTC FACILITIES IN NORTHERN ONTARIO REMOTE COMMUNITIES

COMMUNITY	DATE	FACILITIES VISITED
Bearskin Lake	Jan.11/84	Airport House Airport Garage Airport Waiting Room Airport Power Generator Microwave Power Generator
Sachigo	Jan.12/84	Airport House Airport Garage Airport Waiting Room Airport Power Generator Telsat Power Generator
Slate Falls	Jan.14/84	Telsat Power Generator
Big Trout Lake	Jan.15/84	Airport House Airport Garage Airport Waiting Room
Winisk	Jan.16/84	Airport House Airport Garage/Hotel/Powerhouse Airport/Telsat Power Generator

Estimation of space heating loads in buildings was carried out using the ASHRAE Degree Day method. This method has been shown to give reliable results, especially in cold climates. A comparison of the Degree Day method with hour by hour computer programs such as BLAST showed good agreement (Saskatchewan Research Council, 1983). Space heating design heat losses and infiltration for a building were calculated and used to estimate annual fuel consumption. Design heat loads were compared with the capacity of current heating equipment and fuel consumption was compared to MTC estimates.

Estimations of electrical loads in buildings and at communications sites were determined by identifying the capacity (kW) of electrical equipment and making assumptions with respect to annual operating time. Total capacity was compared with the measured generator output during the site visit. Annual estimates of generator fuel consumption and purchased electricity were made and compared with MTC and Bell Canada estimates.

2.1.3 Phase I Report

Following completion of the site visits and energy audits, a Phase I Report was prepared and presented to the client. The report contained a revised inventory of facilities and presented the energy audit results for each site visited. The Phase I Report also presented preliminary technical options for reducing energy consumption and costs at both the sites which were visited and at other sites known to be very similar, on the basis of data gathered and contained in the revised inventory.

The revised Phase I Report has been incorporated into this Final Report.

2.1.4 Phase II

Following discussion of the Phase I Report with the client and consideration of the technical options identified within it, five (5) energy conserving technical options were selected for detailed assessment:

- Development of retrofit measures for existing MTC airport buildings and power systems based on the Bearskin Lake energy audit
- Development of energy efficient building designs and specifications for new MTC airports
- Assessment of diesel/wind hybrid electrical generating options for the Winisk Airport
- Assessment of intermittent charge diesel systems for MTC remote communications sites
- Assessment of the economic viability of using photovoltaics in conjunction with intermittent charge systems at remote MTC communications sites.

2.1.5 Field Consultations

Following the identification of technical options, further field consultations were carried out with the operators of the remote airport and communications facilities. These consultations served several purposes:

- verification of existing building and equipment specifications

- discussion of desirability/practicality of introducing the identified energy conserving options
- determination of energy conserving initiatives already being considered by MTC and Bell Canada regional personnel
- introduction of possible energy conserving initiatives to Telsat Canada

2.1.6 Prefeasibility Studies

Prefeasibility studies were carried out for each of the technical options listed in 2.1.4 (above). The results of these prefeasibility studies form the bulk of this report.

2.1.7 Final Report

The Final Report presents the finding of both Phases I and II.

2.2 INVENTORY OF REMOTE MTC FACILITIES

2.2.1 Introduction

For the purposes of this Study, the MTC remote facilities have been divided into three groups. These are:

- Airport buildings which use fuel oil for space heating
- Airport power systems used to supply electricity to airport facilities where no community power is available
- Dedicated power systems for communications facilities in communities where no community power is available.

Details on each group are provided below.

2.2.2 Airport Buildings

An inventory of MTC remote airport buildings that use oil for space heating is shown in Table 2.2.

All airport facilities built after 1973 (with the exception of Fort Severn and Ogoki) consist of three basic buildings:

- An 18 X 15 metre garage with the centre section heated by two forced air oil furnaces;
- A 4 X 6 metre waiting room heated by a gravity fed oil stove;

TABLE 2.2

MTC AIRPORT BUILDINGS IN NORTHERN ONTARIO

Community	Construction Date	Facilities	Dimensions
Attawapiskat	1974	House	7m X 12m
		Garage	18m X 15m
		Waiting Room	4m X 6m
Bearskin Lake	1978	House	7m X 12m
		Garage	18m X 15m
		Waiting Room	4m X 6m
Big Trout Lake	1975	House	7m X 12m
		Garage	18m X 15m
		Waiting Room	4m X 6m
Cat Lake[1]	1984	Garage	
Deer Lake	1979	House	7m X 12m
		Garage	18m X 15m
		Waiting Room	4m X 6m
Fort Hope	1975	House	7m X 12m
		Garage	18m X 15m
		Waiting Room	4m X 6m
Fort Severn	1983	House	7m X 7m
	1973	Garage	18m X 15m
	1973	Waiting Room	5m X 3m
Kasabonika	1981	House	7m X 12m
		Garage	18m X 15m
		Waiting Room	4m X 6m

TABLE 2.2 (continued)

Community	Construction Date	Facilities	Dimensions
Kashechewan	1976	House Garage Waiting Room	7m X 12m 18m X 15m 4m X 6m
Lansdowne House[2]	1978	Garage Waiting Room	18m X 15m 4m X 6m
Ogoki	1979	Garage/House	
Pikangikum	1977	House Garage Waiting Room	7m X 12m 18m X 15m 4m X 6m
Sachigo	1979	House Garage Waiting Room	7m X 12m 18m X 15m 4m X 6m
Sandy Lake	1974	House Garage Waiting Room	7m X 12m 18m X 15m 4m X 6m
Webique	1978	House Garage Waiting Room	7m X 12m 18m X 15m 4m X 6m
Weagamow	1976	House Garage Waiting Room	7m X 12m 18m X 15m 4m X 6m
Winisk	1955	House Garage/Hotel/ Power House Waiting Room	6m X 9m 30m X 30m 6m X 6m

---

Notes: 1. Cat Lake airport is under construction and will require additional buildings in 1984.

2. Lansdowne House airport house was destroyed by fire in 1983 and will require replacement in 1984.

- A 7 X 12 metre house used as an airport office and living quarters for MTC personnel

With minor variations such as the use of additional ceiling insulation in more recent buildings, the internal layout, type of construction, windows and doors used, wall insulation, and air tightness does not vary significantly from one airport to another. No building upgrading has been carried out at any of these airports.

At Ogoki a single oil heated building is used as both garage and office/living quarters. At Fort Severn the old runway has been replaced by a new one located approximately 3 km to the west. The old waiting room has been moved to the new runway but the garage and house continue to be located at the old airport site. A new, but smaller house has replaced the original house and an additional, unheated storage bay has been added to the garage which formerly consisted of a single heated bay. At Winisk, there is the single airport building complex built in 1955 by the Federal Department of National Defence. It consists of a large unheated hangar with two heated wings. One wing houses the 3 ONTC power generators, a workshop and a heated garage. This wing is heated with waste heat from the diesel generators. The other wing consists of an office and living quarters operated as a hotel by MTC. Heating is provided by a forced air oil furnace. A small house, heated with its own oil furnace, is attached to the hotel wing for use by the airport manager.

2.2.3 Airport Power Systems

An inventory of MTC/ONTC diesel power systems currently used to provide electricity to MTC airport buildings and ONTC Telsat communications equipment is given in Table 2.3.

The small systems without backup tend to be operated as temporary installations designed to provide local power until community power is available. In Bearskin Lake and Ogoki, however, the airports are either too far from the community for connection to the community power system or community power is not scheduled. These two airport power systems may therefore be assumed to be permanent installations.

The large power system at Winisk used for both airport and communications facilities may also be considered as a permanent installation since the airport is too far from the existing or planned communities for connection to community power.

The small MTC systems, used to provide power to airport buildings, tend to be underloaded and poorly maintained. At one site, several different engines have been used during a twelve month period because of engine failure. Generator cabins tend to be cramped, underlit and uninsulated. Engine silencing is poor. The load consists only of: power for lights in the airport house, garage, and waiting room; power for vehicle block heaters; power for heating system operation (fans, pumps, motors, etc.); and power for tools. This seldom totals more than 8kW in winter and is less in summer.

TABLE 2.3
MTC AND ONTC POWER SYSTEMS FOR AIRPORTS AND COMMUNICATIONS FACILITIES IN NORTHERN ONTARIO REMOTE COMMUNITIES

Community	Load	Airport Construction Date	Prime Power System			Standby Power System		
			Rating (kW)	Engine	Alternator	Rating (kW)	Engine	Alternator
Bearskin Lake	Airport Bldgs	1978	15 (Pritchard)	Perkins 4236	Brown Boveri (18kW)	....	none	....
Cat Lake[1]	Airport Bldgs	1984	....	none	....	....	none	....
Deer Lake[2]	Airport Bldgs	1979	30	Perkins		....	none	....
Fort Severn	Airport Bldgs Telsat Airport Beacon & Runway	1973	20 (Harper)	GM Detroit		20 (Harper)	GM Detroit	
Kasabonika[3]	Airport Bldgs	1981	N/A	Perkins		....	none	....
Ogoki	Airport Bldgs	1979	N/A	Pincore RF20HMI		....	none	....
Sachigo[3]	Airport Bldgs	1979	20	Lister HRW-3	Kamag (24kW)	....	none	....
Winisk	Airport Bldgs Telsat Airport Beacon & Runway	1955	75 (Harper)	GM Detroit	Stanton (75kW)	75(2) (Harper)	GM(2) Detroit	Stanton(2) (75kW)

NOTES:

1. Cat Lake airport is under construction and will require a power system until at least 1985/86 when community power is tentatively scheduled.
2. Deer Lake airport is tentatively scheduled to be supplied with community power in 1985/86.
3. Sachigo and Kasabonika airports will be supplied with community power in 1984.

The larger ONTC systems in Fort Severn and Winisk, are used to provide power to both airport buildings and communications facilities. At Winisk the system is well maintained, but underloaded. The maximum load in the two locations consists of: the airport buildings (about 8kW as above); the Telsat communications facilities (a maximum of about 7.5kW); and the DOT beacon and runway lights (a maximum of about 20kW).

2.2.4 Dedicated Power Systems for Communications Facilities

An inventory of MTC remote diesel power systems currently used to provide power to satellite (Telsat Canada) and microwave (Bell Canada) communications equipment is presented in Table 2.4.

For the purposes of this study, MTC communications facilities can be grouped into two general categories:

. An exchange site:	an automatic telephone exchange has been installed allowing for the use of individual private telephones
. A toll station:	no private telephones are in use; the community is served by a single pay telephone

Exchange sites are located at Angling Lake, Bearskin Lake, Deer Lake, Kasabonika, Kingfisher, Poplar Hill, Sachigo and Wunnumin.

Toll stations are located at Cat Lake, Muskrat Dam, MacDowell Lake, North Spirit, Ogoki and Slate Falls.

TABLE 2.4

MTC POWER SYSTEMS DEDICATED FOR COMMUNICATION FACILITIES IN NORTHERN ONTARIO REMOTE COMMUNITIES

Community	Load	Prime Power System				Standby Power System			
		Manufacturer	Rating (kW)	Engine	Alternator	Manufacturer	Rating (kW)	Engine	Alternator
Angling Lake	Microwave Exchange	Ball	7.5	Lister ST-2	AAE	Ball	7.5	Lister ST-2	AAE
Bearskin Lake[1]	Microwave Exchange	Ball	10	Lister ST-3	AAE G-1260-505	Ball	10	Lister ST-3	AAE S-1260-505
Cat Lake[2]	Telsat Toll Stn.	Ball	7.5	Lister ST-2	AAE	Ball	7.5	Lister ST-2	AAE
Deer Lake[2]	Microwave Exchange	Mechron	10	Lister ST-3	AAE	(3)	20	Lister HR-3	Kohler
Kasabonika[1]	Telsat Exchange	Mechron	10	Lister ST-3	AAE	(3)	20	Lister HR-3	Kohler
Kingfisher	Microwave Exchange	Ball	7.5	Lister ST-2	AAE	Ball	7.5	Lister ST-2	AAE
MacDowell Lake	Microwave Toll Stn.	Mechron	7.5	Lister ST-2	AAE	Mechron	10	Lister ST-3	AAE
Muskrat Dam	Telsat Toll Stn.	Ball	7.5	Lister ST-2	AAE	Ball	7.5	Lister ST-2	AAE
North Spirit	Microwave Toll Stn.	Mechron	7.5	Lister ST-2	AAE	Mechron	10	Lister ST-3	AAE

TABLE 2.4 (continued)

Community	Load	Prime Power System				Standby Power System			
		Manufacturer	Rating (kW)	Engine	Alternator	Manufacturer	Rating (kW)	Engine	Alternator
Ogoki	Telsat Toll Stn.	Ball	7.5	Lister ST-2	AAE	Ball	7.5	Lister ST-2	AAE
Poplar Hill	Microwave Exchange	Mechron	10	Lister ST-3	AAE	(3)	20	Lister HR-3	
Sachigo[1]	Telsat Exchange	Ball	7.5	Lister ST-2	AAE	Ball	20	Lister HR-3	
Slate Falls	Telsat Toll Stn.	Ball	7.5	Lister ST-2	AAE	(3)	7.5	Lister ST-2	Kohler
Wunnumin	Microwave Exchange	Ball	7.5	Lister ST-2	AAE	Ball	7.5	Lister ST-2	AAE

NOTES:

1. Bearskin Lake, Kasabonika, and Sachigo communications facilities will be supplied with community power in 1984.
2. Cat Lake and Deer Lake are tentatively scheduled for community power in 1985/86.
3. These sets have been modified by Bell Canada.

The smaller toll stations are commonly served by 7.5kW diesel generator sets. The larger facilities which have automatic exchanges and temporary living quarters are served by 7.5 or 10 kW prime sets. Each facility has a back-up or standby generator of equal or larger capacity than the prime unit. The diesel generator cabin, housing both prime and standby sets, is commonly located 5 to 10 metres from the Telsat or microwave telecommunications equipment.

Most prime and standby diesel power systems are Ball or Mechron sets. All use Lister engines and either Aircraft Appliance or Kohler induction generators. One of the differences between the Ball and Mechron sets is in the method used to ensure that the oil in the idle engine is kept warm. Ball uses a common oil sump for both prime and standby units so that warm oil from the running engine is available to the idle engine for start-up. Mechron uses separate sumps and electric oil heaters on each unit. When one engine is producing power it is also heating the oil in the idle unit. The Mechron sets also have a more reliable and more easily maintained control system and panel.

Most sets are installed with an environmental control system designed to use some of the engine waste heat to keep the cabin warm. This is to ensure higher power from batteries and lower power requirements during start-up.

All maintenance of the power systems is carried out by Bell Canada. Consultation with Bell Canada field personnel indicates that maintenance includes replacement of major components such as generators and control systems. In fact, as shown in Table 2.4, some sets have been modified to the point that their original manufacturer is no longer relevant. MTC is responsible only for the supply of fuel and installation of new facilities and in isolated cases for the replacement of major components (ie, control panels).

The following general comments can be made about the MTC dedicated communications power systems:

- cabins are too small to allow quick and safe maintenance around the diesel engines and generators, especially in facilities with larger (10-20 kW) sets;
- cabins are uninsulated and their size prevents the safe operation of their stand-alone propane heating systems;
- the absence of stand-alone heating systems, heat storage, effective environmental control systems, and insulation means that in cold weather oil sump heating is not adequate, standby engines do not start, and inside cabin temperatures are seldom above ambient;
- in facilities where one Ball unit has been replaced with a Mechron or other set with a separate oil sump, there is no way of keeping the Ball unit's oil warm when its engine is not running;
- control systems and panels on Ball units tend to be less reliable and need frequent repair;
- at exchange sites, maximum loads often overload the prime power generator engine;

- at small sites with a single toll station, engines are underloaded, except when heating or air conditioning equipment is operating, resulting in high engine wear;

- at many sites, it appears that non-communications loads are placed on the power system by the community leading to uneven loading and engine wear.

2.3 CURRENT FUEL CONSUMPTION AND COSTS

2.3.1 Airport Facilities

The energy audit conducted on the Bearskin Lake airport facilities showed that annual fuel consumption at the Bearskin Airport was about 42,900 litres. Table 2.5 shows the estimated annual fuel consumption, by function, for the Bearskin Lake airport facilities.

The energy audit conducted at Winisk Airport estimated that the annual fuel consumption (including power generation) was 111,700 litres.

TABLE 2.5

BEARSKIN LAKE AIRPORT
ANNUAL FUEL CONSUMPTION, BY FUNCTION

Function	Annual Fuel Consumption (1.)
Space Heating-House	6,800
Space Heating-Garage	14,600
Space Heating-Waiting room	3,500
Electrical Power Generation	18,000
TOTAL:	42,900 l/yr

Based on the energy audit results for the Bearskin Lake airports, the site checks carried out at the airports in Sachigo, Big Trout Lake and Weagamow, and the review of the MTC provided inventory of remote airport facilities and fuel delivery records, the total annual fuel consumption for all MTC remote airports is estimated to be 598,200 litres.

Based on the delivered fuel prices (1983) provided by MTC, the total annual (1983) fuel cost for all MTC remote airport facilities is estimated to be $456,439. In addition, power is purchased from Ontario Hydro at nine sites where community power is available. The annual cost (1983) of this purchased power is estimated to be $127,500.

Table 2.6 provides a detailed breakdown of estimated annual fuel consumption and total energy costs for all MTC remote airports.

"Table 2.6"

TABLE 2.6

MTC REMOTE AIRPORT FACILITIES

- Estimated Average Annual Energy Consumption and Costs (1983)

AIRPORT LOCATION	ANNUAL FUEL CONSUMPTION (LITRES) House	Garage	Waiting Room	Power Generation	Total	ANNUAL FUEL COSTS (1983) Unit Cost ($/l)	Total Cost ($)	ANNUAL PURCHASED POWER COSTS (1983) Consumption (KWH)	Unit Cost ($/kwh)	Total Cost	TOTAL ENERGY COSTS
Attawapiskat	6,800	14,600	3,500	-	24,900	.62	$ 15,438	40,000[6]	.50	$ 20,000	$ 35,438
Bearskin Lake	6,800	14,600	3,500	18,000	42,900	.62	$ 26,598	-	-	-	$ 26,598
Big Trout Lake	6,800	14,600	3,500	-	24,900	.62	$ 15,438.	40,000[6]	.50	$ 20,000	$ 35,438
Cat Lake[1]	-	-	-	-	-	-	-	-	-	-	-
Deer Lake	6,800	14,600	3,500	18,000	42,900	.62	$ 26,598	-	-	-	$ 26,598
Fort Hope	6,800	14,600	3,500	-	24,900	.62	$ 15,438	25,000[6]	.50	$ 12,500	$ 27,938
Fort Severn	2,700	14,600	3,500	50,000[3]	70,800	1.15	$ 81,420	-	-	-	$ 81,420
Kasabonika	6,800	14,600	3,500	18,000[2]	47,900	.62	$ 26,598	-	-	-	$ 26,598
Kashechewan	6,800	14,600	3,500	-	24,900	.62	$ 15,438	25,000[6]	.50	$ 12,500	$ 27,938
Lansdowne House	6,800	14,600	3,500	-	24,900	.62	$ 15,438	25,000[6]	.50	$ 12,500	$ 27,938
Ogoki	-	15,000[4]	-	5,000	20,000	.62	$ 12,400	-	-	-	$ 12,400
Pikangikum	6,800	14,600	3,500	-	24,900	.62	$ 15,438	25,000[6]	.50	$ 12,500	$ 27,938
Sachigo	6,800	14,600	3,500	18,000[2]	42,900	.62	$ 26,598	-	-	-	$ 26,598
Sandy Lake	6,800	14,600	3,500	-	24,900	.62	$ 15,438	25,000[6]	.50	$ 12,500	$ 27,938
Webique	6,800	14,600	3,500	-	24,900	.62	$ 15,438	25,000[6]	.50	$ 12,500	$ 27,938
Weagamow	6,800	14,600	3,500	-	24,900	.62	$ 15,438	25,000[6]	.50	$ 12,500	$ 27,938
Winisk	4,300	11,400[5]	6,000	90,000	111,700	1.05	$ 117,285	-	-	-	$117,285
TOTALS	95,400	230,800	55,000	217,000	598,200		$456,359	255,000	-	$127,500	$583,939

Notes:
1. Currently under construction
2. To be replaced by community power in 84/85
3. Estimate for new installation
4. Estimate for house/garage
5. Hotel consumption
6. Power purchased from Community power system

2.3.2 Communications Facilities

Based on the site inspection of the toll station at Slate Falls and the exchange sites at Bearskin Lake and Sachigo, the review of the site data provided by Bell Canada, and detailed consultations with Bell Canada regional personnel, the total annual fuel consumption for all MTC remote communications facilities is estimated to be about 257,000 litres. This represents an average annual fuel consumption of 18,357 litres per site.

Based on the average delivered fuel price (1983) of 62¢/litre, the total annual (1983) fuel costs for MTC remote communications facilities is $159,340. This is equal to approximately $11,400 per site.

In addition to fuel costs, the MTC remote communications facilities also incur very high maintenance costs. Based on site observations as well as consultations with Bell Canada personnel in Thunder Bay and a review of Bell Canada's recorded expenditures over the period 1981-83, total annual maintenance costs are estimated to average $22,000 per site. This annual average maintenance cost is broken down as follows:

Routine maintenance:	$10,000/yr
Trouble shooting:	$12,000/yr
TOTAL:	$22,000/yr

Routine maintenance involves an overhaul of each engine at 18 month intervals ($4,500 per engine overhaul), and payment of the local agent ($4,000/year). Trouble shooting includes all site visits for non-routine problems such as control system or engine failure. It also includes work performed in Thunder Bay to upgrade system power control equipment. Trouble shooting costs are an average cost and were calculated by subtracting fuel and routine maintenance costs from Bell Canada's three year total operational expenditures. It should be noted that these costs do NOT include any expenses related to the telephone equipment itself.

As shown in Table 2.7, the average annual (1983) operating cost for an individual communications site is $33,400. The total annual (1983) cost for all MTC remote communications sites is $467,600.

TABLE 2.7

MTC REMOTE COMMUNICATIONS FACILITIES
ANNUAL OPERATING COSTS - FUEL AND MAINTENANCE (1983)

Expense Item	Average Site Cost	Number of Sites	Total Cost
Fuel	$11,400	14	$159,340
Routine Maintenance	$10,000	14	$140,000
Trouble Shooting	$12,000	14	$168,000
TOTALS:	$33,400	14	$467,600

2.3.3 Total Annual Costs - MTC Airport and Communication Facilities

Based on the foregoing estimates of costs for both airport and communications facilities, the total annual fuel and diesel generator operating costs are approximately $1 million.

Table 2.8 presents a detailed cost summary.

TABLE 2.8

SUMMARY OF ESTIMATED ANNUAL FUEL AND DIESEL MAINTENANCE COSTS
IN MTC REMOTE FACILITIES
Annual Cost (1983)

Function	Annual Cost (1983)	% of Total
A. Airports-Heating		
1. Houses	$ 62,430	6%
2. Garages	155,740	15%
3. Waiting Rooms	38,530	4%
(sub total)	($256,700)	(25%)
B. Airports-Power		
4. Power System Fuel	$199,740	20%
5. Power System Maintenance	85,000	8%
(sub total)	($284,740)	(28%)
C. Communications		
5. Power System-Fuel	$ 159,340	16%
6. Power System-Maintenance	$ 308,000	31%
(sub total)	($467,340)	(47%)
TOTAL:	**$ 933,699**	**100%**

2.4 OVERVIEW OF POTENTIAL SAVINGS

The following Parts B and C present detailed assessments of energy conserving options for both MTC remote airport and communications facilities.

In each case, the potential cost savings resulting from the implementation of the recommended options are very significant. The following overview presents a brief summary of the potential savings.

2.4.1 Airport Facilities

Existing Buildings: Current fuel consumption for the space heating of airport buildings is approximately 381,200 litres; at the current site fuel prices, the corresponding annual cost is $256,699. Implementation of the buildings retrofit measures, recommended in Sections 3 and 5, would reduce overall annual consumption to about 147,400 litres; at current site fuel prices, the corresponding annual cost is $102,499. This represents an annual savings of $154,200. The required capital expenditure (1984 dollars) is $116,075. Table 2.9 provides details.

Power Systems: The generation of electricity at MTC airports currently consumes 217,000 litres of fuel annually and costs approximately $200,000. Although several of these systems will soon be replaced by community power, there will be a continuing requirement for MTC generated power at sites where access to community power will never be available to the airport facilities. Also, in the case of new airport facilities, there is always a lag time of 5-10 years before community power is available.

TABLE 2.9

MTC REMOTE AIRPORT FACILITIES
POTENTIAL FUEL AND COST SAVINGS
- Airport Buildings

Building	Fuel Consumption (litres)			Annual Fuel Cost *			Capital Expenditure Required**	Simple Payback Period
	Current	Post Retrofit	Savings	Current	Post Retrofit	Savings		
Houses	95,400	44,050	51,350	$ 62,428	$ 30,691	$ 31,837	$ 54,600	1.7 yr.
Garages	230,800	89,100	141,700	$155,736	$ 61,018	$ 94,718	$ 40,150	6 months
Waiting Rooms	55,000	20,100	34,900	$ 38,535	$ 14,517	$ 24,018	$ 21,325	11 months
TOTAL:	381,200	153,250	227,950	$245,599	$106,126	$150,573	$116,075	

* 1983 unit prices

** 1984 dollars

Where there is a requirement for airport power generation (even on an interim basis), the assessment contained in Section 3.5 shows that it is economically attractive to install upgraded diesel sets and to use the diesel waste heat for space heating in the airport garage. Depending on the installation, the recovered waste heat may displace up to 100% of the garage's heating requirements.

New Buildings: Sections 4 and 5 present designs and construction details for new and/or replacement airport buildings -- house, garage, waiting room. When compared to MTC's most current designs, the estimated annual fuel and costs savings are:

- houses - 40% reduction
- garages - 70% reduction
- waiting rooms - 80% reduction

2.4.2 Communications Facilities

Current annual diesel fuel and maintenance costs average $33,400 for each MTC remote communications site. Two options for reducing these costs were assessed:

- Intermittent Charge Diesel Systems
- Photovoltaic/Intermittent Charge Diesel Hybrid System

Intermittent Charge Systems: Section 6 presents a detailed assessment of the costs and benefits of replacing the current conventional diesel sets with an intermittent charge system. The Mechron Energy Ltd. "Cycle Charge" series 2000 system was selected for comparison with the current conventional diesel systems. Annual fuel and maintenance savings were estimated to be $19,200 for an exchange site and $23,600 for a toll station. Table 2.10 provides further detail. Eleven (11) MTC remote communications sites were identified for gradual replacement of current diesel power systems with intermittent charge systems, such as the Mechron Energy Ltd. system. The estimated present value of the resulting savings is approximately 3.1 million dollars.

Photovoltaic/Intermittent Charge Diesel Hybrid System: The assessment of a photovoltaic/cycle charge diesel hybrid system presented in Section 7 shows that a 45 m^2 array would allow complete shut down of the diesel engine at a remote communications site during the summer period. The assessment also shows that the value of PV power during the winter is lower than during the summer, not only because of lower radiation availability, but also because the diesel engine is providing both power and heating. At current PV array prices of $10/peak watt it would not be economically attractive to install PV/diesel hybrid systems at MTC communications sites. MTC should consider use of PV systems, as fuel savers, when array costs drop to about $3.70/peak watt.

TABLE 2.10

MTC REMOTE COMMUNICATIONS FACILITIES
POTENTIAL FUEL/MAINTENANCE COST SAVINGS
- Per Site

Installation	Annual Average Costs -Fuel and Maintenance Costs		Potential Savings/Site	Capital Expenditure Required/Site	Simple Payback
	Current	Cycle Charge 2000			
Exchange Site	$ 33,400	$ 14,200	$ 19,200	$ 87,700	4.6 years
Toll Station	$ 33,400	$ 9,800	$ 23,600	$ 87,700	3.7 years

2.5 OVERVIEW OF STUDY RECOMMENDATIONS

The detailed discussion of technical options, contained in the following Parts B and C result in seven specific overall recommendations. An overview is presented below.

Existing Airport Buildings: The recommended package of energy retrofit measures for existing airport buildings-house, garage and waiting room - provides significant fuel and cost savings as well as a very short pay back period. Therefore,

Recommendation #1: It is recommended that MTC establish an Airport Building Retrofit Program. Given the scope of the recommended measures, it is recommended that 3-5 airports be retrofitted each yar. Retrofit actions should be planned for the normal construction period. All airport facilities would therefore be retrofitted within a 3-5 year period.

New Airport Facilities: The design specifications presented for new airport buildings provide significant and cost effective fuel savings. Therefore,

Recommendation #2: It is recommended that new airport buildings be constructed in accordance with the design specifications presented. It is also recommended that MTC initiate two or three information and training sessions on energy efficient construction techniques for its construction supervisors and/or regular contractors.

Airport Power Systems: The current MTC practice is to install "temporary" construction diesel-generator at new airport sites with the expectation that they wil shortly be replaced by community power. In actual practice these "temporary" installations often remain in operation for 5-10 years before community power is available to the airport. As a result of this current installation method, fuel and maintenance costs are very high and waste heat cannot be utilized for airport building heating. The additional cost of a proper "permanent" installation with waste heat recovery would be easily recouped through savings in fuel, maintenance and heating costs. Therefore,

Recommendation 3: It is recommended that "permanent 15kW generator sets with heat recovery be installed at Cat Lake, Ogoki and future new MTC remote airports.

Recommendation 4: It is recommended that a permanent 50kW dual diesel system, with heat recovery be installed at Bearskin Lake, where community power will never be available to the airport. The Bearskin installation could use one of the present 50 kW engines at Fort Severn when that community receives community power in 1984/85.

Winisk Airport Facilities: The facilities at Winisk are unique and are therefore considered separately in the report. Assessment of the energy conservation options for the airport buildings showed significant potential for fuel savings. The airport also has 3 x 50kW diesel generators. The report assessed the technical and economic feasibility of utilizing a wind/diesel hybrid system to reduce power generating costs while the DAF Indal 50 kW VAWT has a power technical performance in remote settings, its installation at the Winisk airport is not cost-effective. A smaller turbine, the Northwind L-916 HAWT, proved to be cost-effective but has not yet been tested in a severe, remote climate. Stand alone wind turbine systems for use with diesel generator sets are not yet commercially available. Therefore,

Recommendation #5: It is recommended that the Ministry of Energy continue to monitor the development and demonstration of the Northwind L-916 and/or other induction wind turbines in the 15-30 kW range as well as stand-alone synchronous systems in the 50 to 80 kW range. Once their technical reliability in a severe, remote setting is established, the installation of a wind/diesel hybrid system at Winisk should be reassessd.

Communications Facilities: The report concludes that intermittent charge diesel sets, such as the Mechron Energy Ltd, series 2000 system, present a very attractive option for achieving significant fuel and maintenance cost savings at remote communicatins sites. The report also shows that a PV array can provide further fuel savings when used in conjunction with the Mechron "cycle-charged" an intermittent charge diesel system. However, the present cost of PV modules ($10/peak watt) doesn't provide an attractive payback. However, PV module costs are expected to continue to decline; at about $3.70/peak watt, PV will be cost competitive for use with an intermittent charge diesel system at a remote communications site. The small communications load (80 watts) at Angling Lake, makes this site particularly attractive for a PV demonstration. The report notes that one demonstration of the Mechron "cycle charge" series 2000 system is already planned for a Bell Canada repeater site. Therefore,

Recommendation #6: It is recommended that subject to favourable demonstration results further applications of the Mechron "cycle-charge" series 2000 system be encouraged leading to the possible gradual replacement of all existing conventional diesel.

Recommendation #7: It is recommended that, if and when, the current diesel generating sets are replaced at Angling Lake, by an intermittent charge system, the Ministry of Energy should consider incorporating the installation of a demonstration PV array.

PART B

MTC REMOTE AIRPORT FACILITIES

INTRODUCTION

Part B presents a comprehensive assessment of energy conservation and fuel savings opportunities in MTC remote airport facilities in Northern Ontario. Discussion of the opportunities is presented in three sections:

Section 3:	Buildings and Power Systems at Existing MTC Airports (excluding Winisk)
Section 4:	New Buildings and Power Systems for MTC Airports (excluding Winisk)
Section 5:	Buildings and Power System at Winisk Airport

SECTION 3

BUILDINGS AND POWER SYSTEMS AT EXISTING AIRPORTS

3.1 INTRODUCTION

With the exception of Winisk, all MTC remote airports in Northern Ontario consist of three buildings:

- A small house used as an office and temporary living quarters for MTC personnel
- A garage with a large heated area used for vehicle storage and maintenance
- A small heated waiting room

If the airport is not connected to community power, there is also a small diesel generating system to power building lights, tools, appliances, plug-ins, etc. Again, with the exception of Winisk, only airports connected to community power have runway lights and a navigation beacon.

Exhibit 3.1 is an aerial view of a typical MTC remote airport. Exhibit 3.2 shows (from left to right) the airport house, the garage, and waiting room. Exhibit 3.3 is a view of an airport power system shed, usually located close to the garage. Exhibit 3.4 shows a typical diesel generating set.

In the following sections, conservation and fuel saving opportunities for the three buildings and the power systems are presented separately and discussed under the following headings:

- Description
- Existing fuel consumption and costs

- Retrofit measures
- Estimated retrofit costs and fuel savings
- Recommended actions

The description of the facilities and estimation of existing fuel consumption and costs were based on a site visit and detailed energy audit at Bearskin Lake airport and site checks at Sachigo Lake, Weagamow Lake and Big Trout Lake Airports. Retrofit measures, estimation of retrofit costs and fuel savings were based on the Bearskin Lake audit. Recommended actions are for all airport facilities assuming that Bearskin Lake is typical of all airports.

3.2 EXISTING AIRPORT HOUSES

3.2.1 Description

The airport house at Bearskin Lake is a single storey 7m x 12m house. It was constructed in 1978 and is of basic wood frame (2 x 4) construction. The floor plan is shown in Exhibit 3.5. External finish is wood siding and plywood. Internal wall finish is wood panelling and drywall (furnace room only). All walls have RSI 2.1 (R12) fibreglass insulation and a partial vapour barrier. Ceilings are acoustic tile beneath strapping which holds black plastic "vapour barrier" strips between the dividing walls. RSI 3.5 (R20) fibreglass insulation is placed between the trusses over the black plastic. There is a heated crawl space under the house with a dirt floor. The foundation is wood frame with insulation between studs. Windows are single framed double sliding units. Doors are solid wood with wood framing. The house is heated with a Grimsby 67.167C forced air oil furnace rated at 163,000 Btu/hr. Hot water is heated with a propane water heater. Water is supplied by a deep well submersible pump. A heated building extension (about 6m x 2m) is being constructed adjacent to the furnace room and bathroom to house a fire protection water tank.

Air leakage into and out of the house is average. The doors are poor fitting with inadequate weatherstripping. The ceiling vapour barrier is inadequate. There is no vapour barrier over the furnace room or where any of the dividing or external walls meet the roof trusses. There is some infiltration through receptacle covers on external walls, and the kitchen stove exhaust fan damper does not seal adequately (the filter is also almost completely blocked with grease). Windows have fairly good seals except that one or two inside sliders are broken. During the site visit the interior temperature was set at 22°C (71.6°F).

Electrical consumption in the house is mainly for lights, stove, refrigeration, small appliances, and the furnace fan. The estimated maximum load is about 5kW.

Site checks at Sachigo and Big Trout Lake showed that all of the houses were almost identical. The only difference was slightly increased levels of ceiling insulation in the post 1978 buildings.

3.2.2 Current Fuel Consumption and Costs

A summary space heating energy balance for the Bearskin Lake airport house is given in Table 3.1. The detailed energy audit calculations are given in Appendix A. Design exterior and ground temperatures and degree day values below 22°C used in the calculation of annual heating load were those for Big Trout Lake.

As shown in Table 3.1, the annual space heating load is approximately 47,000kWh. Assuming a 65% average oil furnace efficiency and a heating value for fuel oil of 10.6 kWh/litre, the estimated annual fuel consumption is 6800 litres/year. At the current on-site fuel cost of 62¢/litre, this is equivalent to about $4,200/year.

EXHIBIT 3.5

BEARSKIN AIRPORT HOUSE

Floor Plan

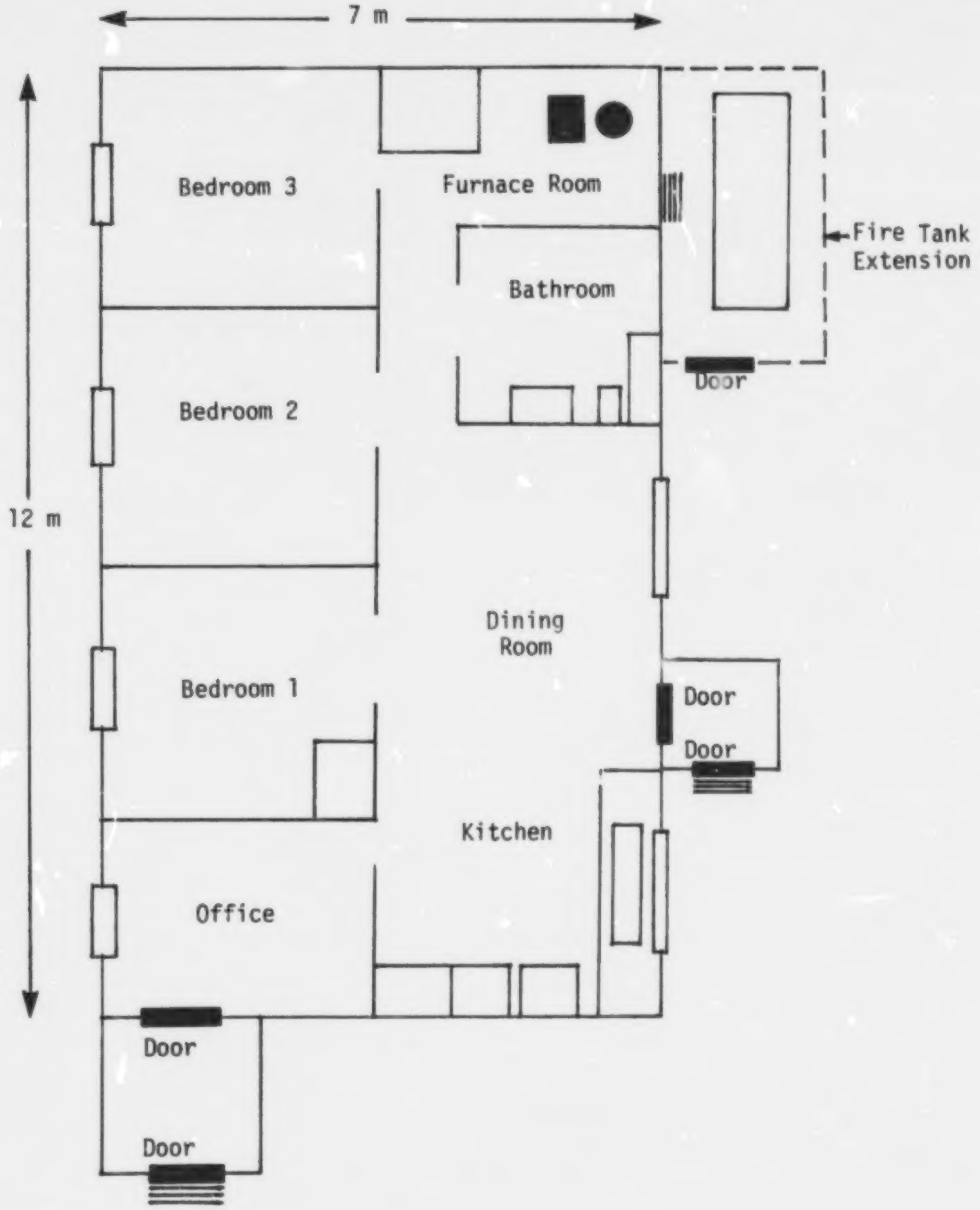

7 m
12 m
Bedroom 3
Furnace Room
Fire Tank Extension
Bathroom
Door
Bedroom 2
Dining Room
Bedroom 1
Door
Door
Kitchen
Office
Door
Door

TABLE 3.1

BEARSKIN LAKE HOUSE
SPACE HEATING ENERGY BALANCE

Design temperatures: - 38°C (-36°F) exterior
2°C (36°F) ground (below frost line)
22°C (65°F) interior

Degree Days: 8500 below 22°C

Building Component	RSI Value	Area m^2	T °C	Design Heat Loss Watts	Annual Heat Loss kWh/yr
Walls	2.4	110	60	2750	9,350
Ceiling	3.8	90	60	1420	4,830
Floor (crawlspace)	0.4	90	20	4500	15,300
Windows	0.7	7	60	600	2,040
Doors	0.7	4	60	340	1,160
				9610	32,680
Infiltration (0.75 air changes per hour)				4120	14,000
TOTAL:				13,730	46,680

Annual Fuel Load (65% burner efficiency)
= 6800 litres/year

3.2.3 Retrofit Measures

Table 3.1 shows that the largest heat losses occur as a result of air infiltration and heat transmission through (in declining order of magnitude) the floor, walls and ceiling. Retrofit measures for each of these areas of heat loss are presented.

In addition to the above measures, two other fuel saving options are:

- improved furnace efficiency through the installation of a retention head burner.
- installation of an automatic programmable thermostat.

Each measure is outlined below.

Automatic Thermostat: Overall house heating requirements can be reduced by installing an automatic programmable thermostat that keeps inside temperatures at, say, 18°C during the day and at 12°C during the night and on weekends. The percentage reduction in heating load from the use of a programmable thermostat may be calculated as follows:

Current inside temperature = 22°C
Time averaged inside temperature, assuming 8 hrs per weekday at 18°C and the remaining time at 12°C

$$= \frac{(40 \times 18) + (128 \times 12)}{168}$$

$$= 13.4°C$$

Assuming a mean outside temperature of -10°C during the heating season, the reduction in heating load will be equal to:

$$1 - \frac{13.4 - (-10)}{22 - (-10)} \text{ or } 27\%$$

The installed cost of a programmable thermostat is estimated to be about $200.00.

Retention Head Burner: In a retention head oil burner, a specially designed head plate provides increased combustion air turbulence during fuel/air mixing and results in higher combustion efficiency. Adding a retention head to existing furnaces of the type used in MTC housing would be expected to improve overall combustion efficiency from 65% to about 75%. This would reduce fuel consumption by:

$$(1/0.65 - 1/0.75)/(1/0.65) \text{ or } 13\%$$

A retrofit retention head conversion costs about $500.

Infiltration Reduction (Air Sealing): There are several ways that air infiltration in MTC airport houses can be reduced. The simplest approach would be to upgrade the weatherstripping on exterior doors and to replace warped doors as necessary. All broken or poor fitting window sliders should also be replaced or sealed. A tight window seal can be achieved by using a film of heat shrinkable plastic film covering the complete window. The kitchen vent damper should be replaced with a unit which remains tightly closed even during windy conditions (kitchen vent filters should also be replaced). Attic exfiltration can be reduced by sealing the existing vapour barrier against the top plates of exterior and interior walls. This can be carried out from the attic (see Figures 3.1, and 3.2). The attic hatch should also be well sealed (see Figure 3.3) and the furnace chimney breach sealed where the chimney passes into the attic (see Figure 3.4). All attic sealing work is described in more detail in a recent Energy Mines and Resources Canada publication (Air Sealing Homes, 1984).

The above measures would be expected to reduce air infiltration from about 0.75 air changes per hour to about 0.5 air changes per hour -- still adequate to provide sufficient combustion air and keep humidity levels down. Infiltration heat losses would therefore be reduced by (0.75 - 0.5)/0.75 or 33%.

The cost of the above measures is estimated to be as follows (though labour costs are difficult to determine):

Materials (weatherstripping, sealants, etc.)	$ 200
Labour	$ 750
	$1,000

Wall Insulation: The most effective way of decreasing heat losses through exterior walls, while at the same time reducing wall infiltration, would be to add 5 cm (2") styrofoam to the outside of the building. The insulation could be attached to the existing siding and new siding would have to be placed over the insulation. Some strapping might have to be used to support the insulation and siding. The addition of 5 cm of styrofoam plus the siding would increase the wall RSI value by about 1.8 to a total of 4.2. This would reduce wall heat losses by:

Exhibit 3.1: AERIAL VIEW OF MTC REMOTE AIRPORT

Exhibit 3.2: BEARSKIN AIRPORT FACILITIES

Exhibit 3.3: BEARSKIN AIRPORT DIESEL SHED

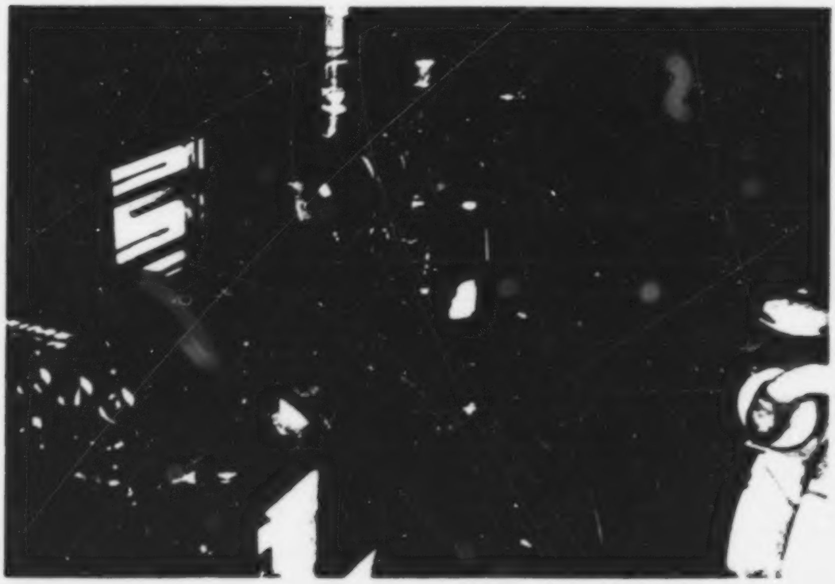


Exhibit 3.4: BEARSKIN AIRPORT DIESEL GENERATOR

FIGURE 3.1

SEALING EXTERIOR WALL TOP PLATES

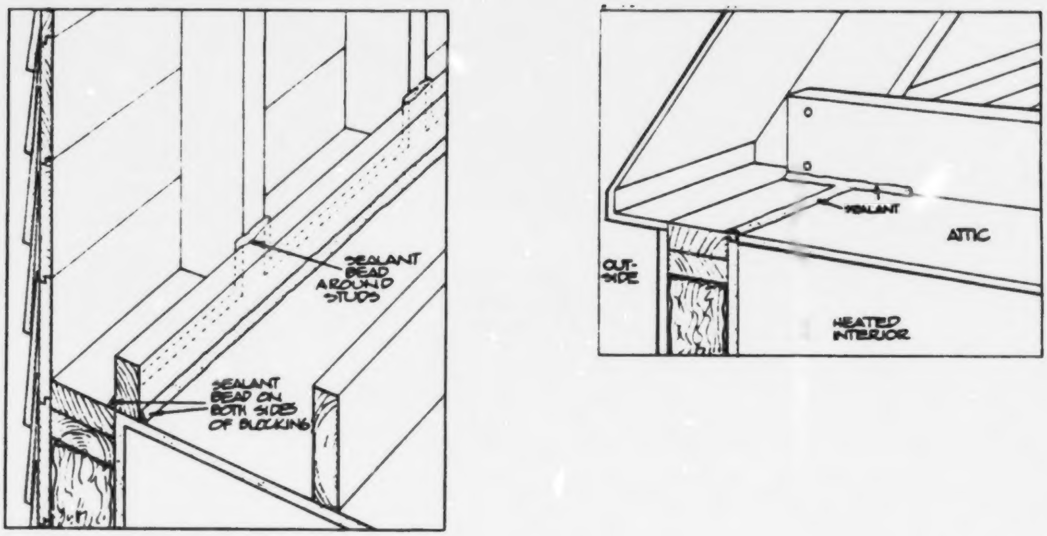

SEALANT BEAD AROUND STUDS
SEALANT BEAD ON BOTH SIDES OF BLOCKING
SEALANT
ATTIC
OUT-SIDE
HEATED INTERIOR

FIGURE 3.2

SEALING INTERIOR WALL TOP PLATES

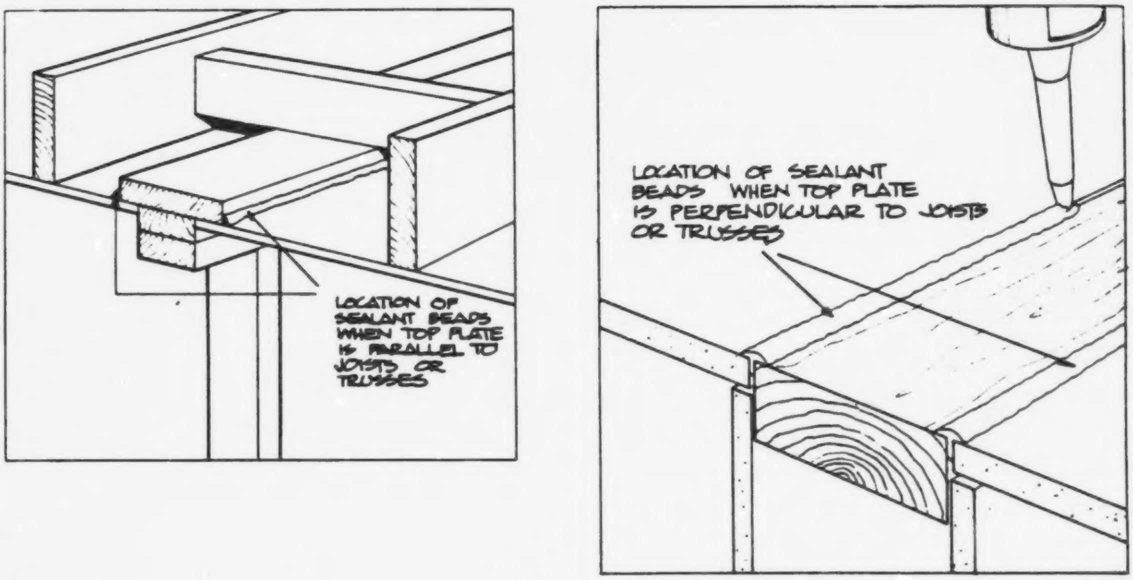

LOCATION OF SEALANT BEADS WHEN TOP PLATE IS PARALLEL TO JOISTS OR TRUSSES
LOCATION OF SEALANT BEADS WHEN TOP PLATE IS PERPENDICULAR TO JOISTS OR TRUSSES

FIGURE 3.3

SEALING ATTIC HATCHES

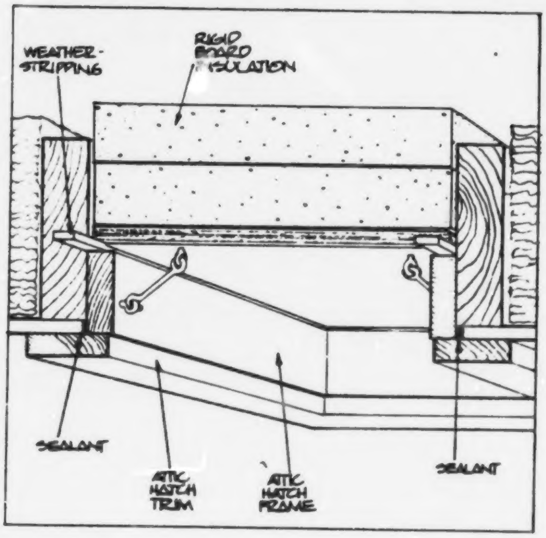
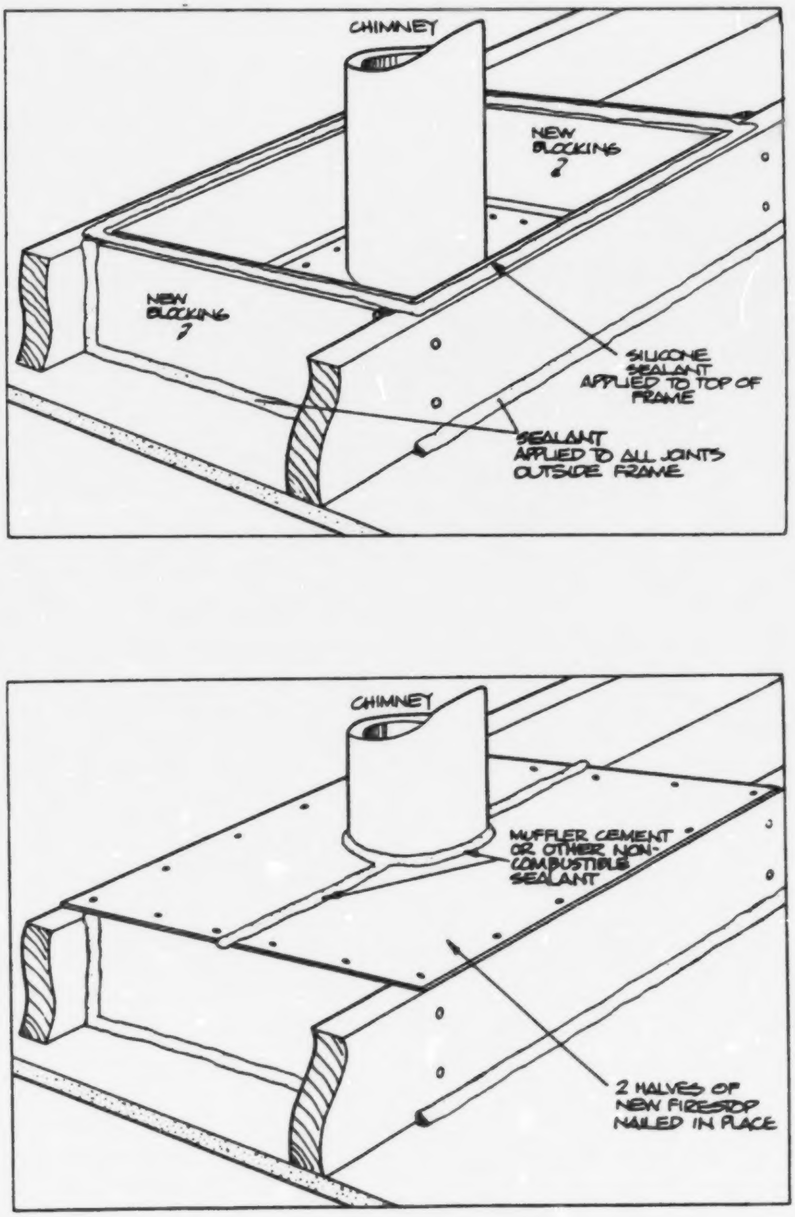

WEATHER-STRIPPING
RIGID BOARD INSULATION
SEALANT
ATTIC HATCH TRIM
ATTIC HATCH FRAME
SEALANT

FIGURE 3.4

SEALING AROUND CHIMNEYS


CHIMNEY
NEW BLOCKING
NEW BLOCKING
SILICONE SEALANT APPLIED TO TOP OF FRAME
SEALANT APPLIED TO ALL JOINTS OUTSIDE FRAME
CHIMNEY
MUFFLER CEMENT OR OTHER NON-COMBUSTIBLE SEALANT
2 HALVES OF NEW FIRESTOP NAILED IN PLACE

(1/2.4 - 1/4.2)/(1/2.4) or 43%.

The cost of insulating the walls and installing new siding is estimated to be as follows:

Insulation	$110m^2$ @ $8.75/$m^2$	$ 962.50
Siding	$110m^2$ @ $3/$m^2$	$ 330.00
Labour and freight		$1,500.00
		$2,792.50

Floor Insulation: The only pratical way that the current dirt floor in the crawl space could be insulated would be to lay down styrofoam insulation on the floor and cover it with a 5 cm (2") layer of sand for fire protection. This task would not be easy because of the restricted access to the crawl space. The best method of installation would be to remove some of the lower exterior wall siding below the room floor level and add the insulation and sand from the outside. The addition of 5 cm of styrofoam plus 5 cm of sand to the crawl space floor would increase the floor RSI by about 1.8. In the preliminary energy audit, it was assumed that the average design ground temperature below the house is 2°C and that the average thermal resistance of the dirt floor is RSI 0.4. With this assumption, adding 5 cm of styrofoam would decrease heat losses through the dirt floor by (1/0.4 - 1/2.2)/(1/0.4) or 82%. Because the dirt floor is close to ground level, however, adding insulation to the floor will actually lower the ground temperature, especially near the perimeter of the house. It is more realistic, therefore to assume a new design ground temperature that is an average of the current ground design temperature and the outside design temperature (-38°C) ie, -20°C. The actual reduction in heat losses through the floor will therefore be approximately equal to:

$$\left\{\frac{18 - 2}{0.4} - \frac{18 - (-20)}{2.2}\right\} \Big/ \frac{18 - 2}{0.4} \quad \text{or } 57\%$$

It is important to note now, however, that because the design ground temperature below the house is less than 0°C there is a larger risk of freezing the water supply pipe from the well and a larger risk of frost heave of the foundation walls. To prevent freezing of the water system, the area around the well should be left uninsulated.

The cost of insulating the dirt floor is estimated to be as follows:

Insulation 90 m^2 @ \$8.75/m^2	\$ 787.50
Sand or gravel 4.5 m^3 @ \$20/m^3	\$ 90.00
Labour	\$1,000.00
	\$1,877.50

This measure can only be considered at airports where there is a local supply of sand or fine gravel.

Ceiling Insulation: The installation of extra fibreglass insulation into the attic space of the airport houses would be a simple and low cost method of reducing heat loss and could be carried out in conjunction with the attic air sealing measures described above. The addition of RSI 3.5 fibreglass batts over the present RSI 3.8 fibreglass insulation would reduce ceiling heat losses by (1/3.8 - 1/7.3)/(1/3.8) or 48%.

The cost of insulating the ceiling is estimated as follows:

Insulation $90m^2$ @ $\$3.50/m^2$	$315
Labour and freight	$300
	$615

3.2.4 Estimated Retrofit Costs and Savings

The retrofit measures that offer the greatest fuel savings for the least investment can be determined by applying the percent savings estimated in Section 3.2.3 (above) to the heat losses and fuel efficiencies estimated in the original space heating energy balance (Table 3.1).

Table 3.2 shows the effect of sequentially implementing the retrofit measures described above starting with the lowest cost measure.

Table 3.2 shows that all of the above retrofit measures except wall insulation, have a simple payback of less than 5 years. The long pay back period associated with wall insulation does not present an attractive investment opportunity.

The estimated total cost of implementing the retrofit measures with a pay back of less than 5 years is about $4,200. In order to calculate the corresponding reduction in fuel consumption, it is necessary to determine the new heat balance that would exist after implementation. Table 3.3 shows that the new annual heating load would be 22,700 kWh. This represents a 51% reduction in the current heating load.

In addition, the installation of the retention head burner would increase furnace efficiency from the present 65% to approximately 75%. Consequently, total

TABLE 3.2
RETROFIT MEASURES FOR MTC AIRPORT HOUSING

Measures (Assuming they are carried out sequentially)	**Reduction in Heat Losses** (kWh/year)	**Reduction in Fuel Consumption** (l/year)	**Savings** ($)	**Cost** ($)	**Simple Payback** (Years)
1. Automatic Thermostat	0.27 x 46,680 = 12,600	1830	1100	200	0.2
2. Retention Head Burner	-	0.13 x (6800-1830) = 650	390	500	1.3
3. Attic Insulation	0.48 x 4830 x (1-0.27) = 1700	210	130	615	4.7
4. Air Sealing	0.33 x 14,000 x (1-0.27) = 3400	430	260	1000	3.8
5. Floor Insulation	0.57 x 15,300 x (1-0.27) = 6400	805	500	1877.50	3.8
6. Wall Insulation	0.43 x 9350 x(1-0.27) = 2900	370	220	2792.50	12.7

TABLE 3.3
TYPICAL AIRPORT HOUSE
SPACE HEATING ENERGY BALANCE
- Post Retrofit

Building Component		**Revised Heat Loss**
Doors	0.73[a] x 1160[b]	= 850 kWh/year
Windows	0.73[a] x 2040[b]	= 1500 kWh/year
Walls	0.73[a] x 9350[b]	= 6850 kWh/year
Ceiling	0.73[a] x 0.52[c] x 4,830[b]	= 1850 kWh/year
Floor	0.73[a] x 0.43[c] x 15,300[b]	= 4800 kWh/year
Infiltration	0.73[a] x 0.67[c] x 14,000[b]	= 6850 kWh/year
TOTAL:		= 22,700 kWh/yr
Fuel consumption (75% burner efficiency)		= 2850 l/year

Notes: (a) .73 is a constant factor representing the impact of the thermostat set back

(b) current heat loss, as presented in Table 3.1

(c) reduction in current heat loss, resulting from retrofit measure annual fuel consumption would be approximately 2,400 litres; this represeents a total annual fuel oil reduction of 58%. At the current on-site fuel cost of 62¢/litre, annual space heating costs for the airport house would therefore be about $1,800 in contrast to the present $4,200 for a savings of $2,300/year.

The overall annual savings from implementing the 5 measures in the recommended retrofit package would be about $2,300. The total cost of the retrofit package has been shown to be about $4,200. Consequently, the simple pay back period is about 1.8 years.

3.2.5 Recommended Action

It is recommended that the five retrofit measures with a pay back of less than 5 years be implemented as a single operation at each airport. This would minimize the costs of labour and transportation.

3.3 EXISTING AIRPORT GARAGES

3.3.1 Description

The 18m x 15m airport garage at Bearskin Lake was constructed in 1978 and is of wood frame construction. It is constructed as an uninsulated shell with 5m high walls and 18m roof trusses. Two insulated internal walls divide the garage into three bays, the centre one having an insulated ceiling. Two large single sliding doors (4.9m x 3.7m), one located at either end of the centre bay, provide access to the bay which is about 8.5m wide. Access to the smaller bays on either side is through a sliding door at one end of each bay. The floor plan is shown in Exhibit 3.6. Internal and external finish is plywood. Internal wall insulation is 4" fibreglass batts and ceiling insulation is 6" fibreglass batts. There is no apparent vapour barrier. The floor is poured concrete slab on grade. The sliding doors are solid wood with no weatherstripping. Heating is provided from two Grimsby 67.167C forced air furnaces rated at 163,000 Btu/hr. There are insulated furnace rooms located in each of the side bays and each furnace provides hot air to different ends of the centre bay. Single hot air and return air ducts connect the furnace to the heated bay.

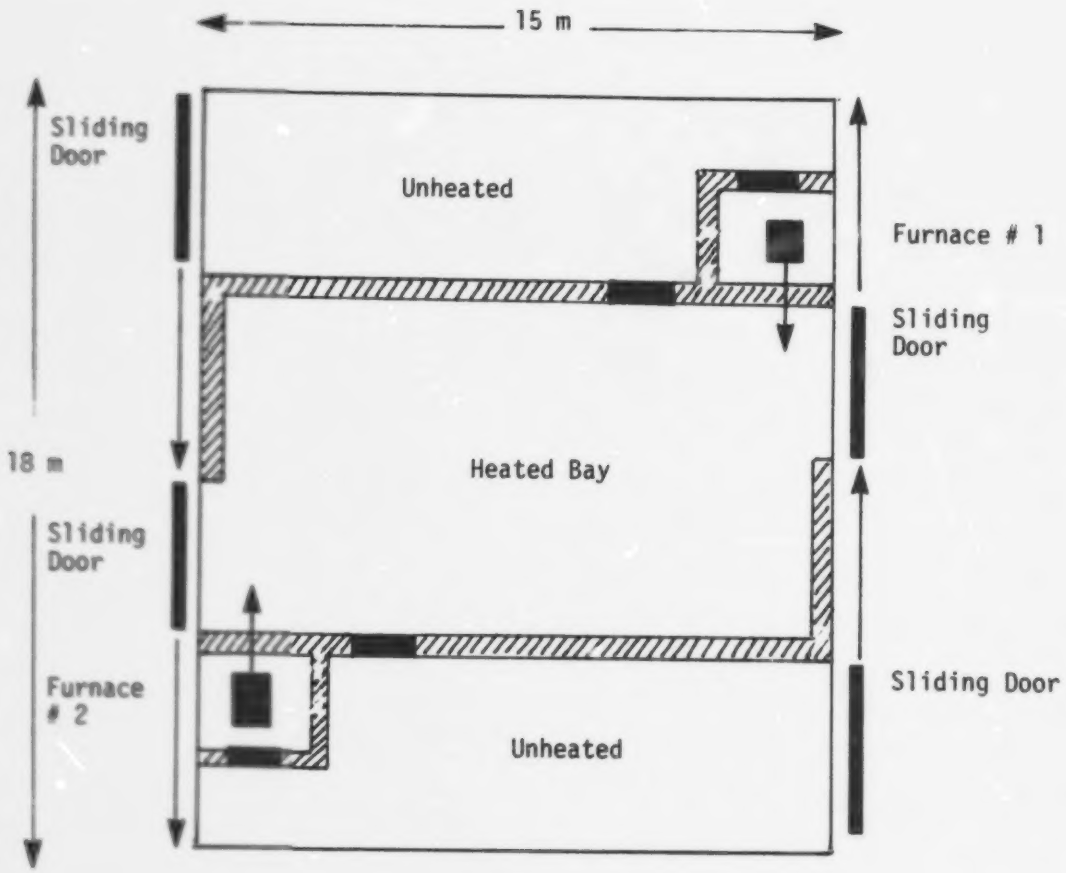
Air leakage through the sliding doors is high. At an outside temperature of -35°C (-31°F) one furnace running continuously was able to maintain an interior temperature of about 10°C (50°F).

Electrical consumption in the garage is mainly for lights, tools, vehicle plug-ins, and furnace fans and represents an estimated maximum load of about 6kW.

EXHIBIT 3.6

BEARSKIN AIRPORT GARAGE

Floor Plan


15 m
Sliding Door
Unheated
Furnace # 1
Sliding Door
18 m
Heated Bay
Sliding Door
Furnace # 2
Sliding Door
Unheated

▨ Insulated Walls

Site checks at Sachigo and Big Trout Lake showed that slightly more ceiling insulation is used in post-1978 buildings. Big Trout Lake's garage doors have weatherstripping and a hand tightened screw arrangement which reduces air infiltration through some parts of the doors.

3.3.2 Current Fuel Consumption and Costs

A summary space heating balance for the Bearskin Lake airport garage is given in Table 3.4. The detailed calculations are given in Appendix A and Appendix B. Design exterior and ground temperatures used were those used in the house energy balance calculations. A design interior temperature of 10°C was used. A degree day figure of 5,000 below 10°C (9,000 below 50°F) was used.

The initial audit calculations showed that door infiltration losses are particularly significant in the Bearskin Lake airport garage. Consequently, it was considered important to make a more accurate estimate of door losses using a methodology developed by the Building Engineering Group at the University of Waterloo (BEG, 1983). The methodology allows the user to calculate wind induced infiltration losses from local wind and temperature data as well as from assumed or measured values for the amount of time the door is open and the crack area around the door. The methodology also allows the user to calculate stack effect losses (suction created by the natural buoyancy of air in the building). In MTC airport garages, however, these stack effect losses can be assumed to be negligible because the door extends the full height of the heated section.

Calculation of door infiltration losses as a function crack area around the door also means that the effect of weatherstripping on infiltration losses can be estimated. Calculation of losses as a function of wind speed and direction means that the effect of garage siting on infiltration can be estimated. Appendix B summarizes the door infiltration loss methodology and estimates infiltration heat losses for the existing Bearskin Lake airport garage.

As shown in Table 3.4, the annual space heating load is approximately 100,600 kWh. Assuming a 65% average oil furnace efficiency and a heating value for fuel oil of 10.6 kWh/litre, the estimated annual fuel consumption is approximately 14,600 litres/year. At the current on-site fuel cost of 62¢/litre, this is equivalent to about $9,050/year.

The design heat loss is estimated to be 40,000 watts (137,000 Btu/hr). This was confirmed, as a reasonable estimate during the site when one of the 163,000 Btu/hr furnace, running continuously, was just able to maintain a 10°C inside temperature when the outside temperature was close to the design temperature of -38°C.

TABLE 3.4

BEARSKIN LAKE GARAGE
SPACE HEATING ENERGY BALANCE

Design Temperatures: - 38°C (-36°F) exterior
2°C (36°F) ground
10°C (50°F) interior

Degree Days: 5000 below 10°C

Building Component	RSI Value	Area m^2	T °C. Loss	Design Heat Loss Watts	Annual Heat Loss (kWh/yr)
Walls	2.4	200	48	4000	10,000
Ceiling	3.8	130	48	1645	4,100
Floor	0.7	130	8	1485	3,700
Doors	2.4	35	48	700	1,800
				7,830	19,600
Infiltration (from Appendix C)					81,000
	TOTAL:				100,600

Annual Fuel Load (65% burner efficiency)
= 14,600 litres/year (3200 gallons/year)

3.3.3 Retrofit Measures

Table 3.4 shows that the most significant source of heat loss in the Bearskin Lake airport garage is through infiltration around the large sliding doors. Floor loss is also high, but no practical retrofit measure exists for retrofitting the concrete floor. The only remaining surfaces accessible to retrofit are the ceiling and walls. However, as shown in Table 3.4, heat losses through the ceiling are not significant in comparison with the infiltration and wall transmission losses. Consequently, retrofit measures should be concentrated on reducing infiltration losses, reducing wall transmission losses, and improving efficiency of the heating system.

Consequently, four retrofit measures are considered:

- weatherstripping for sliding doors
- wall insulation
- automatic set back thermostat
- retention head burners

Each measure is assessed below. It should be noted that these measures are interactive. For example, an automatic lowering of the interior temperature will reduce infiltation losses as well as transmission losses. Similarly, upgrading the efficiency of the heating system will reduce the unit cost of the space heat generated by the furnace.

Weatherstripping for Sliding Doors: The most appropriate style of weatherstripping for the bottom of the main sliding doors would be a new pile type seal recently introduced by several manufacturers. This attaches to the bottom of the door in an aluminum track. The same style could be used to seal the side of the door which runs inside the wall with the seal attached to the wall. On the closing side of the door a bubble or leaf seal could be attached to the jamb. The estimated cost of this weatherstripping made of "arctic vinyl" would be less than $200 per door and could be installed in 2 person days. The total cost of retrofit would therefore be less than $1,000 per garage.

To estimate the savings that would accrue from the recommended weatherstripping, the methodology given in Appendix B may be used. Assuming that the night temperature is set back from 10°C to 5°C for 12 hours, the time-averaged mean inside temperature becomes 7.5°C. The weatherstripping can be assumed to reduce the gap around the door to about 0.1% (BEG, 1983). Table 3.5 uses the equation from Appendix B and shows the calculation of savings due to weatherstripping.

TABLE 3.5

CALCULATION OF SAVINGS
- Weatherstripping Garage Doors

	Door #1	Door #2	Total
Current infiltration heat loss (kWh)	37,100	43,900	81,000
Infiltration heat loss after set back only (kWh)(see below)	32,500	38,400	70,900
Infiltration heat loss with weatnerstripping and set back (kWh)	11,600	13,800	25,400
Savings due to weather-stripping (kWh)	20,900	24,600	45,500

Assuming that upgrading the heating system improves the furnace efficiency to 75%, then the fuel savings from weatherstripping (using a fuel energy content of 10.6 kWh/litre) will be:

$$\frac{45,500}{10.6 \times 0.75} = 5720 \text{ litres/yr}$$

At a fuel price of 62¢/litre, the annual savings will be about $3500 per year which gives a simple payback for weatherstripping of less than one year.

Wall Insulation: The most appropriate means of reducing wall heat losses is to install extruded polystyrene sheets on the outside of the heated section walls, securing them with battens or covering them with aspenite or plywood panelling. If 5cm styrofoam were used, the wall resistance would be increased from RSI 2.4 to 4.1. The cost of styrofoam to cover the two walls ($150m^2$) at \$8.75 per m^2 would be about \$1300. Freight and installation costs would be approximately \$1,500 for a total cost of about \$2,800.

Table 3.6 shows an estimation of the savings from adding wall insulation.

TABLE 3.6

CALCULATION OF SAVINGS
- Addition of Wall Insulation

Current wall heat losses	10,000 kWh/yr
Wall heat losses after setback (see below)	8,750 kWh/yr
Wall heat losses with RSI 4.1 in side walls and set back	6,000 kWh/hr
Savings due to adding insulation	2,750 kWh/yr
Savings at 75% furnace efficiency	350 l/yr
Savings at 62¢/litre	$217/yr

The simple pay back for addition of wall insulation is almost 13 years and is therefore not considered to be an attractive investment.

Automatic Set Back Thermostat: A single automatic thermostat could be used to control both furnaces in the garage. These units, which can be programmed to change the inside temperature setting up to 4 times a day, can be installed for less than $200.

An automatic thermostat which sets back the inside temperature to 5°C for 12 hours each night will reduce all heat losses by a ratio of .875. The derivation of this ratio is shown in Table 3.7.

TABLE 3.7

CALCULATION OF REDUCTION RATIO

$$\frac{\text{Time averaged inside temperature - Mean outside temperature}}{\text{Current inside temperature - Mean outside temperature}}$$

$$= \frac{7.5 - (-10)}{10 - (-10)}$$

$$= 0.875$$

Assuming that the weatherstripping described above is carried out, the total heat losses before the automatic set back thermostat is installed will be 48,500 kWh/year, as shown in Table 3.8.

TABLE 3.8

CALCULATION OF ANNUAL GARAGE HEAT LOSSES
- After Installation of Weatherstripping

Transmission Losses	Doors	1,800
	Walls	10,000
	Ceiling	4,000
	Floor	3,700
Infiltration Losses*		29,000
		48,500 kWh/yr

* Calculated from the equation in Appendix B assuming a 0.1% gap area and no set back.

The annual savings resulting from the installation of an automatic set back thermostat can be determined from the following equation:

Heat Savings

= Current Annual Heat Loss x (1-Reduction ratio)

= 48,500 kWh x (1 - 0.875)

= 6100 kWh/yr

Assuming a furnace efficiency of 75% (as per modifications below) and a heat value for fuel oil of 10.6 kWh/litre,

$$\text{Fuel savings} = \frac{6100 \text{ kWh}}{10.6 \times 0.75}$$

$$= 760 \text{ l/yr}$$

At an on-site fuel cost of 62¢/litre, this saving is equal to about $470/year. The pay back period is therefore approximately 5 months.

Retention Head Burner: The furnaces used in the Bearskin airport and other airport garages in Northern Ontario appear to be maintained once a year; given the age of the units they would be expected to have fuel burning efficiencies of about 65%. Most do not have air filters which could lead to dust build-up on the heat exchanger and a reduction in efficiency.

The efficiency of the garage heating system could be improved by the installation of retention head burners on the hot air furnaces and by maintaining the furnace filter access door in a closed position. The installed cost of each retention head burner is about $500 for a total garage cost of $1,000.

These modifications would be expected to improve heating system efficiency from about 65% to 75%. The heating requirements after main door weatherstripping and installation of the automatic set back thermostat was calculated above to be 48,500 x 0.875 = 42,400 kWh/year.

The further savings from improving the heating system efficiency by 10%, using a fuel energy value of 10.6 kWh/litre, would therefore be:

$$\frac{42,400}{10.6}\left\{\frac{1}{0.65} - \frac{1}{0.75}\right\} = 820 \text{ litres/year}$$

This saving is worth about $530/year at a fuel cost of 62¢/litre. The simple pay back is about 2 years.

3.3.4 Estimated Retrofit Costs and Savings

Table 3.9 shows the energy balance on a typical airport garage after implementing the three retrofit measures described above which have paybacks of less than 5 years.

TABLE 3.9

TYPICAL AIRPORT GARAGE ENERGY BALANCE
POST RETROFIT

Building Component	Revised Heat Loss (kWh/year)
Doors	1,600
Walls	8,750
Ceiling	3,500
Floor	3,200
Infiltration	25,350
	42,400
Fuel consumption at 75% burner efficiency:	5,300 l/yr
Heating cost at 62¢/litre	$3,300/year

The total cost of the weatherstriping, set back thermostat and retention head burners is estimated to be $2,200. The savings would be $9,050 - $3,300 or $5,750/year. The simple pay back would therefore be less than 6 months.

3.3.5 Recommended Action

Three measures: door weatherstripping, a set back thermostat, and retention head burners offer very fast pay backs and should be implemented as a package in each MTC garage.

3.4 EXISTING AIRPORT WAITING ROOMS

3.4.1 Description

The airport waiting room at Bearskin Lake is a 3.5m x 6m one room wood frame structure with an uninsulated floor over an unheated crawl space and RSI 2.1 (R12) insulation in the walls and ceiling. There are two wood frame doors and 3 small vinyl framed double sliding windows. Inside and outside finish is plywood. Heat is provided by a Coleman 4116B-93 oil stove rated at 47,000 Btu/hour.

Air leakage through the two doors is high. Both doors are badly warped and have no weatherstripping. The oil stove is able to maintain the interior temperature at about 10°C (50°F) with an exterior temperature of -35°C (-31°F).

Electrical consumption in the waiting room (2 x 60 watt light bulbs) may be neglected.

3.4.2 Current Fuel Consumption and Costs

A summary space heating balance for the Bearskin Lake airport waiting room is given in Table 3.10. The detailed calculations are given in Appendix A. The design exterior temperature assumed was the same as that used in the garage energy balance calculations.

As shown in Table 3.10, the annual space heating load is approximately 18,650 kWh. Assuming a 50% average oil stove efficiency and a heating value for fuel oil of 10.6kWh/litre, the estimated annual fuel consumption is 3,500 litres. At the current on-site fuel cost of 62¢/litre, this is equivalent to $2,200/year.

TABLE 3.10

BEARSKIN LAKE WAITING ROOM
SPACE HEATING ENERGY BALANCE

Design temperature: -38°C. (-36°F) exterior
10°C. (50°F) interior

Degree days: 5000 below 10°C.

Building Component	RSI Value	Area m^2	T °C.	Design Heat Loss Watts	Annual Heat Loss kWh/yr
Walls	2.4	40	48	800	2,000
Ceiling	2.4	20	48	400	1,000
Floor	0.4	20	48	4800	12,000
Windows	0.7	3	48	200	500
Doors	0.7	4	48	275	650
				6475	16,150
Infiltration (2 air changes per hour)				985	2,500
	TOTAL:			7460	18,650

Annual Fuel Load (50% burner efficiency)
= 3500 litre/year (770 gallons/year)

3.4.3 Retrofit Measures

Table 3.10 shows that the main sources of heat loss are infiltration through the poorly fitting doors and transmission through the uninsulated floor. Reducing infiltration losses to 0.75 air changes per hour through replacing the doors with weatherstripped units would cut the design heat loss by 615 watts. Adding 2" styrofoam insulation under the floor would reduce the design heat loss by 4300 watts. These savings could be realized, however, only if the small oil stove used to heat each building can be adjusted to a very low setting. Without an adjustable stove setting, or use of a propane heater with a lower output, reducing heat losses will only increase room temperatures, not save fuel.

3.4.4 Estimation of Retrofit Costs & Savings

The potential savings are 615 + 4350 = 4965 watts, which, assuming 5000 degree days below 10°C and 50% burner efficiency, represents a fuel savings of 2330 l/yr or about $1,440 at 62¢/litre fuel cost. The size of these savings would allow replacement of doors (estimated at $1,000), addition of insulation (estimated at $200), and replacement of the existing oil stove with a new oil or propane unit, with a smaller capacity and output (estimated at $400), for a simple payback of just over a year.

3.4.5 Recommended Action

It is recommended that MTC carry out the upgrading of all airport waiting rooms with the above measures.

3.5 EXISTING AIRPORT POWER SYSTEMS

3.5.1 Description

By the end of 1984, only MTC airports at Bearskin Lake, Ogoki, Fort Severn, and Cat Lake will have their own power systems. Fort Severn has a permanent dual 50kW diesel generating system while Bearskin, Ogoki, and Cat Lake have temporary portable diesel or gasoline sets rated at 10 to 15kW. The airports at Ogoki, Fort Severn and Cat Lake will eventually be connected to community power, while Bearskin Lake will probably always need its own power system because of its distance from the community. Some type of permanent power system will therefore ultimately be required at Bearskin Lake. The system could be either a dual system that can meet all the power needs of a full airport (including runway lights and a navigation beacon) or a single smaller unit that could meet the current needs. It may also be worthwhile to install single smaller permanent units at Ogoki and Cat Lake because access to community power could be 5 years or more away at these airports.

The temporary unit currently in use at Bearskin Lake is a Pritchard Engineering 15kW, 15kVA, 1800 rpm 120/240 volt, 60Hz, generator set with a 26HP perkins 4 cylinder, 4 stroke, naturally aspirated liquid cooled engine (mounted radiator and fan), and a Brown Boveri Model 295 alternator rated at 18.7kW, 23.4 kVA, 0.8 power factor, 120/240 volts. The unit is housed in a small shed behind the airport garage. Routine maintenance appears to be inadequate: a continuous fuel leak of approximately 20 litres/day was observed during the site visit.

A similar temporary 15kW generator was being used at Sachigo Lake airport during the site check. Several sets have had to be replaced at Sachigo during the past year due to engine failure.

The main drawbacks from the use of the portable diesel units therefore appear to be as follows:

- system maintenance tends to be neglected resulting in frequent engine failure and replacement
- the system is not installed in a controlled environment resulting in cold restarts, heavy battery wear, and high fuel consumption
- the system controls are not designed for long term reliability and on-site trouble-shooting
- there is no means by which the diesel engine waste heat can be used for space or water heating in the airport facilities.

3.5.2 Current Fuel Consumption and Costs

Two load measurements were made during the Bearskin Lake site visit. The observed loads were about 5kW at 6:00 pm, and 8kW at 9:00 am. when vehicle block heaters were in use. The maximum winter load would be expected to be about 12kW (5kW house, 6kW garage, and block heaters, 1kW external lights, etc.). The average winter load is estimated to be about 5kW. In summer, the generator is often shut down.

The engine exhaust temperature at the loads measured was 204°C (400°F) with the inlet at -30°C.

An 8 kW load would mean that the set is loaded to about 50% of its capacity. Assuming that the engine is a 26 HP engine, then at full load the fuel consumption would be expected to be about 0.42 lbs/BHP/Hr and at 50% load would be expected to be about 0.47 lbs/BHP/Hr. Assuming an 80% generator efficiency the fuel consumption is 3.4 l/hr at 8kW. Detailed power system calculations are given in Appendix A.

The average power consumption at remote airports, which obtain power from community systems, varies between 25,000 kW/yr and 40,000 kWh/yr depending primarily on their level of use. These airports normally have run-way lights, but many tend to have lower building usage than Bearskin because of their proximity to the community. Power consumption at Bearskin Lake airport, and other similar airports which generate their own power, is estimated to be about 30,000 kWh/yr. This is consistant with a 5kW average load and a 3 month summer shutdown. Generator fuel consumption at this low average load of 5kW would be approximately 2.7 l/hr or 18,000 l/yr (9 months). At the current on-site fuel price of 62¢/l this would cost $11,000/yr.

3.5.3 Retrofit Measures

At Bearskin Lake, where community power will not likely ever be available, the present temporary arrangements should be replaced by a permanent system as soon as possible. The two options are a 15kW set that would meet current demands and a twin 50kW set that would be able to meet the demands of a full airport with runway lights and a DOT beacon.

At Ogoki and Cat Lake, where community power may be available during the next 5-10 years, the options are to continue using temporary power systems or to install a 15kW permanent power system until community power is avilable.

In any option where a permanent power system is to be used, it would be advantageous to install the set(s) in one of the unheated bays of the airport garage. The cost of installation would be reduced, a new building would not be required, and the waste heat from the generator set could be used to heat the garage. The standard MTC airport garage design has a central heated bay and two outer unheated bays (see Section 3.3). The central bay is heated by two forced air furnaces, located in small furnace rooms in the unheated bays. The site visit and preliminary energy audit at the Bearskin Lake garage showed that even without thermal upgrading, one of the furnaces is capable of maintaining the garage at 10°C at the local design low temperature of -38°C. The second furnace is therefore only used as a back-up and could be replaced by a liquid cooled diesel generating set which would provide power to the airport and waste heat to the garage. Any excess waste heat not required for heating during the spring, summer and fall, would be automatically vented.

Even if the diesel generator set was installed in the above fashion for a 5-10 year period in the airport garages at Cat Lake and Ogoki, the extra cost of having a reliable permanent power system would be recouped in lower garage heating costs, lower diesel engine maintenance costs, and lower diesel engine fuel consumption. At Bearskin Lake a permanent diesel system with heat recovery could be installed in the existing garage to allow the addition of runway lights, and a DOT beacon. This would reduce the existing high diesel maintenance costs and garage heating requirements. There is also the possibility of moving the liquid cooled dual 50kW system recently installed at MTC Fort Severn to Bearskin Lake when Fort Severn obtains community power. This system could readily be installed at Bearskin and used in the manner described above.

3.5.4 Estimated Retrofit Costs and Savings

As per the above discussion, this section estimates retrofit costs and savings for:

- installation of a single 15kW generator set at existing MTC airports not currently served by community power (ie, Bearskin Lake, Cat Lake, Ogoki)
- permanent installation of dual 50kW generator sets at Bearskin Lake or relocation of Fort Severn's dual 50kW generator set to Bearskin Lake.

Single 15kW Generator Set: The preliminary energy audits at Bearskin Lake and Sachigo airports indicated that the average electrical load during the winter season at an airport without runway lights or a DOT beacon is about 5kW. The maximum load is estimated to be about 12kW. In summer, power is only required on an intermittent basis. The following load schedule may therefore be assumed for a typical year:

Load	Operating Time	Power Consumption
12kW	10%	10,500kWh
6kW	15%	7,900kWh
3kW	45%	11,800kWh
0kW	5%	---
Not Operating (summer)	25%	---
		30,200kWh

Table 3.11 gives performance data for a generator set consisting of a typical 25HP liquid cooled diesel engine, 15kW alternator, 1.5 HP radiator fan, and 0.77 effective exhaust heat recovery.

Using the performance data from Table 3.11 and the above operating load schedule, the annual fuel consumption, waste heat recovery rate, and the heating season waste heat recovery contribution were calculated. Details are provided in Table 3.12.

The methodology used to calculate diesel fuel consumption, recoverable waste heat, and equipment size is given in Appendix C.

The estimated fuel consumption of 18,600 litres/yr in Table 3.12 agrees well with estimates determined during the preliminary energy audit at Bearskin Lake. Table 3.12 also shows that, if the waste heat recovered from the generator set is used to heat the airport garage, heat would be available at a rate between 21 and 67 MJ/hr, depending on the electrical load; and a total of 325,000 MJ/yr would be available during the heating season.

Section 3.3 showed that in a thermally upgraded garage, the annual heating requirement would be 42,400 kWh/yr (153,000 MJ/yr), the design heat load would be 17 kW (61 MJ/hr), and the annual fuel consumption would be 5,300 l/yr. The waste heat could therefore supply a significant fraction of the garage heating requirement. The actual contribution would depend on how well the high electrical load matched the garage heating load.

TABLE 3.11

PERFORMANCE DATA* FOR A 15KW DIESEL GENERATING SET CONSISTING OF A TYPICAL 25 HP NATURALLY ASPIRATED ENGINE, 15KW ALTERNATOR, 1.5 HP RADIATOR FAN, AND 0.77 EFFECTIVE EXHAUST HEAT RECOVERY

Electrical Load (kW)	Total Load (kW)	Engine Loading (%)	Alternator Efficiency (%)	Fuel Consumption (kg/hr.kW)	Exhaust Temp. (°C)
12	13.1	71%	80	0.24	380
6	7.1	38%	74	0.27	308
3	4.1	22%	66	0.35	227
0	1.1	6%	60	0.49	114

Coolant: 50/50 glycol/water
Flow rate: 2450 l/hr (9 IGPM)
Thermostat Setting: 82°C

Exhaust Rate: 100 kg/hr

Electrical Load (kW)	Fuel Energy (MJ/hr)	Recoverable Jacket Heat (MJ/hr)	Recoverable Exhaust Heat (MJ/hr)	Jacket Radiation (MJ/hr)	Alternator Heat Losses (MJ/hr)
12	147	42	25	15	12
6	119	39	22	13	9
3	85	31	14	12	8
0	38	15	6	6	3

* Assumptions:

Generator efficiency at full load = 0.81

Engine power output at full load $= \frac{13.9\text{kW} + 1.1\text{kW}}{0.81}$

$= 18.5\text{kW}$ (25 HP)

TABLE 3.12

FUEL CONSUMPTION AND WASTE HEAT RECOVERY USING THE 15kW GENERATOR SET DESCRIBED IN TABLE 3.11

Electrical Load (kW)	Operating Time (hrs/yr)	Fuel Consumption (l/yr)	Recoverable Waste Heat (MJ/hr)	Recoverable Waste Heat (MJ/yr)
12	876	4,060	67	59,000
6	1,314	4,020	61	80,000
3	3,942	10,110	45	177,000
0	438	460	21	9,000
TOTAL	6,570	18,650		325,000

Assuming that the electrical load distribution on a design day was the same as the average throughout the year, the average design day waste heat contribution would be:

(0.1 x 67) + (0.15 x 61) + (0.45 x 45) + (0.05 x 21)
= 37 MJ/hr

If the design temperature is -38°C and the garage is to be maintained at 10°C, the design heat loss is 61/(10-(-38)) = 1.27 MJ/hr°C. The waste heat will therefore provide all the heating requirements of the garage if the outside temperature is above -19°C [10-(37/1.27) = -19°C]. The number of degree days below -19°C at Big Trout Lake is about 500 per year. Therefore, the residual heat load will be 1.27 x 24 x 500 = 15,500 MJ/yr. The percentage contribution from the waste heat will therefore be:

(153,000 - 15,000)/153,000 or 90%.

The percentage design day contribution will be 37/61 or 61%.

Full specifications for a 15kW generator set and waste heat recovery system developed by the Study Team as well as a suggested layout for installation in a MTC airport garage are given in Appendix D. Few changes to a garage would be required. One furnace would be removed, a couple of new walls would need to be built and a new thermostat installed that would control delivery of waste heat into the garage and turn on the back-up furnace when required.

The estimated cost of the 15kW set including waste heat recovery equipment is $27,900. In general, a lag time of about 5-10 years is common between the time when the airport garage/diesel generator becomes operational and community power is installed. Assuming an average diesel generator system lifetime of 7 years and a discount rate of 7%, the annual capital cost of the system would be $5,200.

Table 3.13 shows that the cost of power from such a system is 62¢/kWh, and the net annual cost $18,700/yr.

The current cost of providing power at MTC sites without community power (including frequent replacement of the portable sets) is estimated to be $14,000 for fuel (18,000 l/yr @ 62¢/l) and $10,000/yr for maintenance. Installation of a 15kW permanent system with heat recovery would therefore cost less than the current temporary power system and produce power at a cost not much higher than community power (currently about 50¢/kWh). It might be worthwhile therefore continuing to operate the system during the heating season, even after connection to community power. The electrical load on the generator set could be controlled such that it never provided more waste heat than was required for garage heating.

TABLE 3.13

NET COST OF OPERATING A PERMANENT 15KW DIESEL GENERATING SET WITH HEAT RECOVERY AT MTC AIRPORTS

Annual cost of system	$ 5,200	
Estimated Annual Maintenance	$ 5,000	
Annual Fuel Cost: 18,600 l/yr @ 62¢/litre	$11,500	
Total:		$21,700
Fuel Savings from use of Waste Heat: 140,500 MJ/yr @ 75% efficiency & 62¢/litre		$ 3,000
Net Annual Operating Cost		$18,700
Unit Cost of Power: 30,000 kWh/yr @$18,700/yr	62¢/kWh	

Dual 50kW Generator Set: DOT directional navigation beacons are not installed at remote MTC airports unless there is a reliable power supply. A reliable supply means community power or the existence of a back-up generator set. The only MTC airports not connected to community power which have back-up generators are Winisk and Fort Severn. If runway lights and a DOT beacon are to be installed at Bearskin Lake either the airport must have a back-up generator set or a separate smaller diesel system would have to be installed. It would be more economic to install a single dual system that could meet all loads as at Winisk and Fort Severn.

A DOT beacon and runway lights are estimated to draw a maximum of about 20 kW. This would raise the maximum electrical load at an airport from 12kW to 32kW. A load schedule in a typical year for an airport with a beacon and runway lights might therefore be as follows:

Load	Operating Time	Power Consumption
32kW	5%	14,000kWh
25kW	15%	33,000kWh
12.5kW	50%	55,000kWh
6.25kW	30%	16,000kWh
		118,000kWh

Assuming that a 50kW alternator and a 5kW (6.7 HP) radiator fan were used:

Generator efficiency = 0.87

$$\text{Engine power output at full load} = \frac{50 + 5}{0.87}$$

$$= 63 \text{ kW } (85 \text{ HP})$$

Table 3.14 gives performance data for a generator set consisting of a typical 85 HP liquid cooled diesel engine, 50kW alternator, 6.7 HP radiator fan, and 4" exhaust heat recovery silencer.

Table 3.15 gives the annual fuel consumption, the waste heat recovery rate and the waste heat contribution for the above load schedule based on the performance data from Table 3.14.

Table 3.15 shows an estimated annual fuel consumption of about 70,000 litres/yr, a heat recovery rate of between 100 and 220 MJ/hr depending on the electrical load, and a total year-round waste heat availability of 1,200,000 MJ. Since a 50kW set would be running year-round only a fraction of this waste heat would be useful for garage heating. However, the minimum heat recovery rate is 100 MJ/hr which is higher than the design heating load of 61 MJ/hr (17 kW) for the upgraded garage. A 50kW set could therefore be expected to provide all the garage heating throughout the year. (It should be noted that this would influence the payback on garage retrofit actions for Bearskin Lake discussed in Section 3.3).

Full specifications and a suggested layout developed by the Study Team for installation of twin 50kW generator sets and waste heat recovery system in an MTC garage are given in Appendix E. The estimated equipment cost for the twin 50kW sets, including waste heat recovery equipment, is $80,500. This estimate also includes $3,500 for an automatic transfer switch to start the standby unit when the prime unit goes down.

TABLE 3.14

PERFORMANCE DATA FOR A 50 KW DIESEL GENERATING SET CONSISTING OF A TYPICAL 85 HP NATURALLY ASPIRATED LIQUID COOLED ENGINE, 50 KW ALTERNATOR, 6.7 HP EXHAUST FAN AND 4" EXHAUST HEAT RECOVERY SILENCER

Electrical Load (kW)	Total Load (kW)	Engine Loading (%)	Alternator Efficiency (%)	Fuel Consumption (kg/hr.kW)	Exhaust Temp. (°C)
32	37	67	87	0.25	287
25	30	55	86.5	0.25	260
12.5	17.5	32	86	0.34	187
6.25	11.25	21	86	0.37	149

Coolant: 50/50 Glycol/Water
Flow Rate: 9,000 l/hr (33 IGPM)
Thermostat Setting: 82°C

Exhaust Rate: 370 kg/hr

Electrical Load (kW)	Fuel Energy (MJ/hr)	Recoverable Jacket Heat (MJ/hr)	Recoverable Exhaust Heat (MJ/hr)	Jacket Radiation (MJ/hr)	Alternator Heat Losses (MJ/hr)
32	480	140	80	47	20
25	390	114	65	38	15
12.5	310	109	38	33	9
6.25	220	79	21	28	6

TABLE 3.15

FUEL CONSUMPTION AND WASTE HEAT RECOVERY USING THE 50 KW GENERATOR SET DESCRIBED IN TABLE 3.14

Electrical Load (kW)	Operating Time (hrs/yr)	Fuel Consumption (l/yr)	Recoverable Waste Heat (MJ/hr)	(GJ/yr)
32	438	5,500	220	96
25	1,314	13,400	179	235
12.5	4,380	35,700	147	644
6.25	2,628	15,000	100	263
TOTAL	8,760	69,600		1,238

There are two main differences between the current Fort Severn diesel generator sets and those specified in Appendix E. The Fort Severn units have turbo charged engines instead of naturally aspirated engines, and there is no heat recovery equipment. Turbo charging means that fuel consumption is improved by about 5% but recoverable waste heat is reduced by about 7%. If a set were moved to Bearskin Lake airport garage, however, there would still be more than sufficient waste heat for garage heating. It would also be a relatively simple task to add a heat recovery system during installation.

3.5.5 Recommended Action

Because of the potential savings in fuel and maintenance costs and the possibility of producing power cost effectively in winter on a permanent basis even after connection to community power, it is recommended that permanent 15kW generator sets with heat recovery, as specified in Apendix D, be installed in the MTC airport garages at Cat Lake and Ogoki. It is also recommended that similar generator sets be installed at all new airports built by MTC in remote Northern Ontario (see Section 3.3).

At Bearskin Lake, where community power will never be available, it is recommended that because of the high cost of the twin 50kW system, its more than sufficient waste heat recovery contribution, and the relative ease in moving a 50kW set from Fort Severn to Bearskin Lake, a single 50kW generating set with heat recovery be installed now at Bearskin Lake in the airport garage, according to the specifications and layout in Appendix E. In addition, one of the 50kW sets, now at Fort Severn should be moved to Bearskin Lake airport for standby use when Fort Severn obtains community power. This would allow work to commence on runway lights and a beacon at Bearskin Lake, provide a permanent 50kW power system for Bearskin Lake, and leave a standby unit at Fort Severn for emergency use when the airport is connected to community power. It should be noted that, prior to the selection of system size at Bearskin Lake airport, actual electrical peak loads resulting from the installation of the new beacon and runway lights should be confirmed. It may be preferable to use a 35kW system.

SECTION 4
NEW MTC REMOTE AIRPORT FACILITIES

4.1 INTRODUCTION

The preceding Section 3 addressed energy retrofit measures in existing MTC remote airport facilities. However, in addition to existing airport facilities, MTC is planning to construct new remote airport facilities over the next five years. These include:

- The completion of the Cat Lake airport
- New airport facilities at Muskrat Dam, Poplar Hill and North Spirit Lake
- The replacement of the airport house at Lansdowne House which was destroyed by fire in 1983
- The replacement of the airport manager's house at Winisk

Each of the new airports will require similar facilities to those currently found in the existing airports, namely: a house/office; a garage; and, a waiting room. The construction of new airport facilities provides an opportunity to incorporate cost-effective new energy efficient designs and construction details.

This section, therefore, assesses and recommends specific energy-efficient design and construction details for:

- new/replacement airport houses
- new airport garages
- new airport waiting rooms

4.2 NEW HOUSES FOR MTC REMOTE AIRPORTS

4.2.1 Background

The houses built for MTC airports between 1973 and 1982 are very similar and follow the basic design described in Section 3. In 1983, a new design based on Ontario Hydro accommodation specifications was built at Fort Severn and a similar house design has been drawn up for the airport at Lansdowne House to replace the building which burned down in 1983.

Following discussions with MTC remote airport personnel, it was decided that the most practical means of introducing new, more energy efficient airport housing into the Ministry's existing construction routines was to use a "staged" approach. That is, the Study Team was requested to first review the Ministry's most recent design - the Ontario Hydro design specified for Lansdowne House - and to suggest modifications with respect to design and/or construction detail which would reduce space heating costs. Secondly, the Study Team was requested to develop and present construction details for a "super energy-efficient" airport house.

This "staged" approach recognizes:

- the need to allow suitable time for the training of MTC building contractors in energy efficient construction techniques

- the desirability of providing the Ministry with alternative designs which would enable comparison and evaluation of trade-offs between increased construction costs versus reduced space heating costs.

In developing each building design, it was assumed that the basic functional requirements of an MTC remote airport accommodation building are:

- an office for administration of airport operations
- kitchen and washroom facilities for regular day use and occasional overnight use
- sleeping accommodation for 4-6 out-of-community MTC personnel
- oil or propane water heating
- oil or propane fired space heating

In addition, the building must be able to be constructed by local labour under the supervision of an outside contractor, materials must be able to be brought in by air, and site preparation must be able to be carried out with local airport or community equipment.

It should be noted that the Winisk airport facilities are unique and are consequently discussed separately in Section 5.

4.2.2 Upgraded Version of Lansdowne House Airport House Design

Current Design: A copy of the current MTC design for the house at Lansdowne House is shown in Appendix F. A review of the current MTC/Ontrio Hydro design for the new airport house at Lansdowne House showed that in contrast to previous MTC airport houses, the current design:

- is for a slightly smaller house
- incorporates a pillar foundation with an unheated crawl space rather than a wood frame foundation and heated crawl space.

The changes appear to be to reduce cost but, because of the unheated crawl space, are likely to result in a shorter lifespan for the building and more frequent pipe freezing. The new design does not take advantage of new super energy efficient construction techniques now becoming commonplace in some new housing, nor does it attempt to group water and heating facilities in ways which would reduce the risk of freezing.

Modified Design: A modified design developed by the Studio Team for the new airport house scheduled to be constructed at Lansdowne House is illustrated in Exhibits 4.1 through 4.5. Building specifications are given in Appendix G. The modified design:

- provides maximum utilization of passive solar gain in high use areas (office and kitchen/dining room)

- utilizes some relatively simple energy efficientbuilding techniques that will reduce fuel consumption

- groups water and heating services in a central location

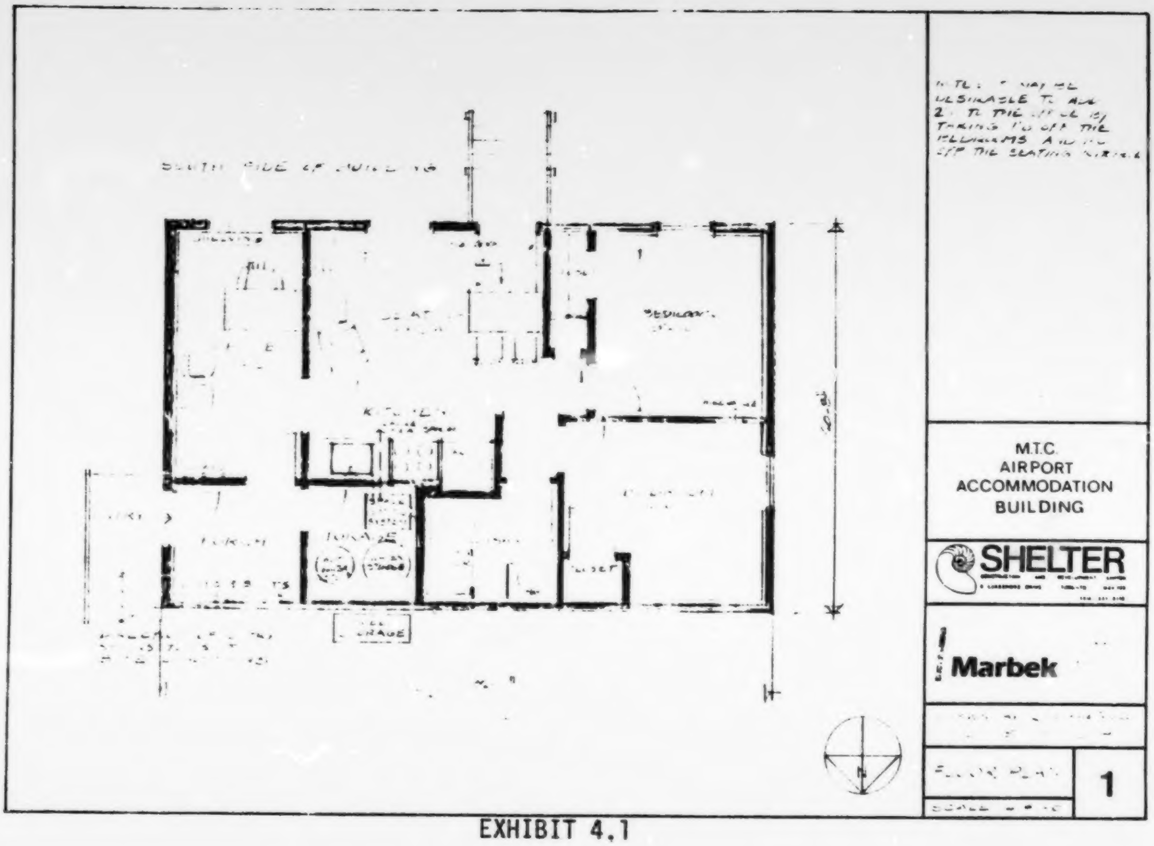

SOUTH SIDE OF BUILDING
BEDROOM
KITCHEN
PORCH
STORAGE
CLOSET
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
SHELTER
Marbek
FLOOR PLAN
1
SCALE

EXHIBIT 4.1

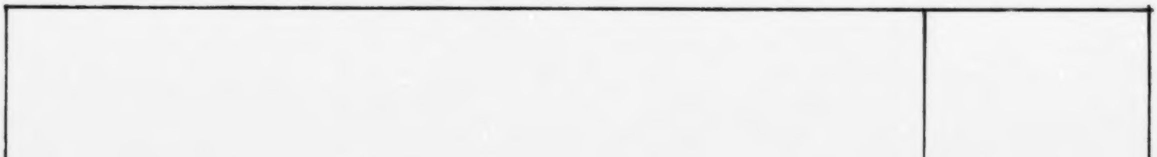

DINING/KITCHEN
MECHANICAL & STORAGE
HEATED CRAWL SPACE
DETAIL DWG 3
DETAIL DWG 4
M.T.C
AIRPORT
ACCOMMODATION
BUILDING
SHELTER
Marbek
DRAWN BY
DATE 5
SECTION
2
SCALE

EXHIBIT 4.2

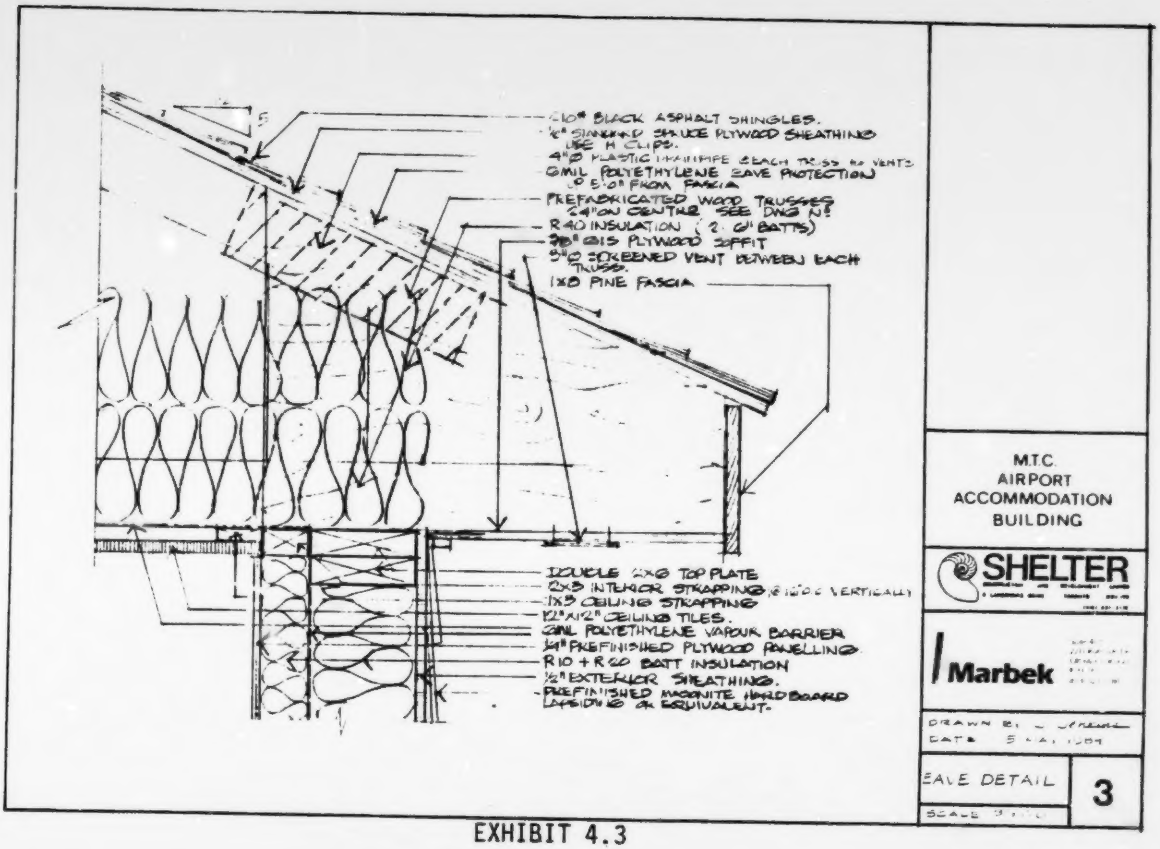

10# BLACK ASPHALT SHINGLES.
1/2" STANDARD SPRUCE PLYWOOD SHEATHING USE H CLIPS.
4"Ø PLASTIC DRAINPIPE @ EACH TRUSS AS VENTS
6MIL POLYETHYLENE EAVE PROTECTION UP 5'-0" FROM FASCIA
PREFABRICATED WOOD TRUSSES 24" ON CENTRE SEE DWG Nº
R40 INSULATION (2. 6" BATTS)
3/8" G1S PLYWOOD SOFFIT
3"Ø SCREENED VENT BETWEEN EACH TRUSS.
1X8 PINE FASCIA
DOUBLE 2X6 TOP PLATE
2X3 INTERIOR STRAPPING @ 16" O.C. VERTICALLY
1X3 CEILING STRAPPING
12"X12" CEILING TILES.
6MIL POLYETHYLENE VAPOUR BARRIER
1/4" PREFINISHED PLYWOOD PANELLING.
R10 + R20 BATT INSULATION
1/2" EXTERIOR SHEATHING.
PREFINISHED MASONITE HARDBOARD LAPSIDING OR EQUIVALENT.
5
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
SHELTER
Marbek
DRAWN BY
DATE 5 MAY 1984
EAVE DETAIL
3
SCALE

EXHIBIT 4.3

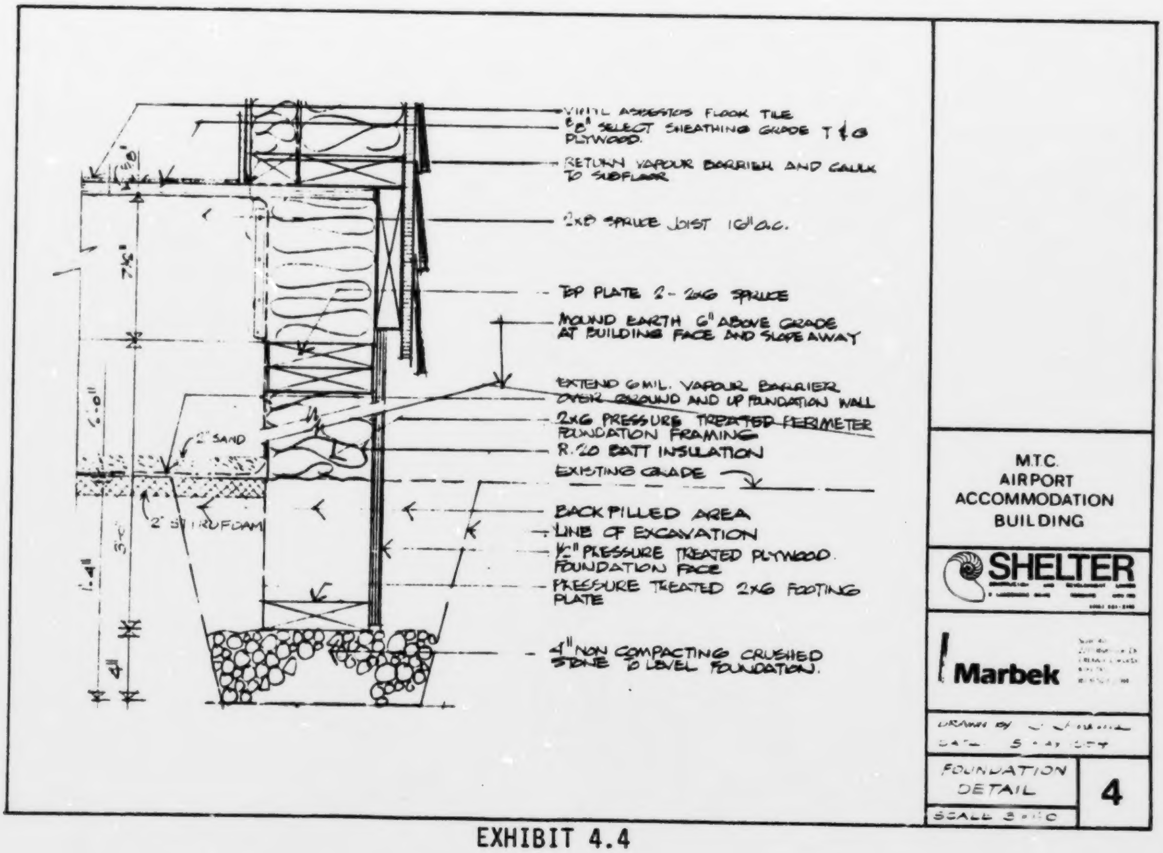

VINYL ASBESTOS FLOOR TILE
5/8" SELECT SHEATHING GRADE T & G PLYWOOD.
RETURN VAPOUR BARRIER AND CAULK TO SUBFLOOR
2X8 SPRUCE JOIST 16" O.C.
TOP PLATE 2 - 2X6 SPRUCE
MOUND EARTH 6" ABOVE GRADE AT BUILDING FACE AND SLOPE AWAY
EXTEND 6MIL. VAPOUR BARRIER OVER GROUND AND UP FOUNDATION WALL
2X6 PRESSURE TREATED PERIMETER FOUNDATION FRAMING
R.20 BATT INSULATION
EXISTING GRADE
BACKFILLED AREA
LINE OF EXCAVATION
1/2" PRESSURE TREATED PLYWOOD. FOUNDATION FACE
PRESSURE TREATED 2X6 FOOTING PLATE
4" NON COMPACTING CRUSHED STONE TO LEVEL FOUNDATION.
2" SAND
2" STYROFOAM
6'-0"
3'-0"
1'-4"
4"
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
SHELTER
Marbek
DRAWN BY
DATE 5 MAY 1984
FOUNDATION DETAIL
4
SCALE

EXHIBIT 4.4

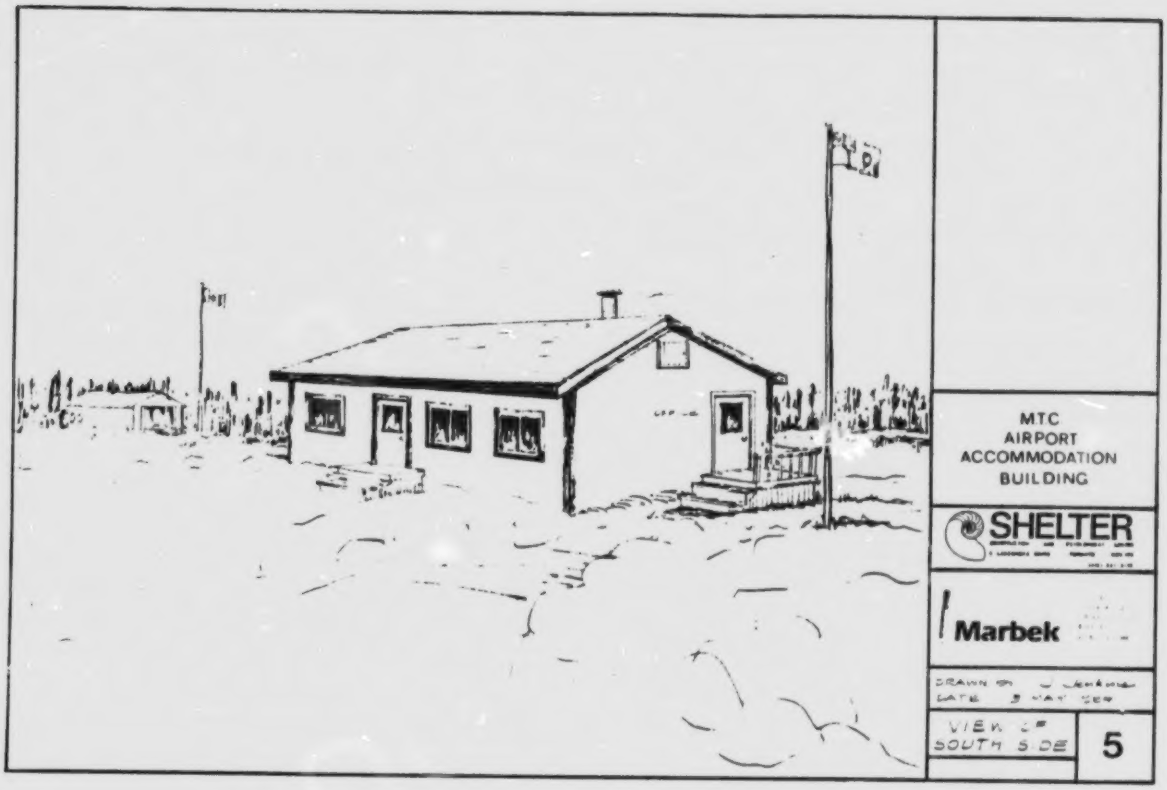

OFFICE
MTC
AIRPORT
ACCOMMODATION
BUILDING
SHELTER
Marbek
DRAWN BY J. JENKINS
DATE 3 MAY [illegible]
VIEW OF
SOUTH SIDE
5

EXHIBIT 4.5

The key features of the modified design are as follows:

- the porch/air lock has been moved inside to eliminate deterioration of unsupported outside porches
- the office and kitchen/dining room are on the same side of the house so that maximum passive solar gain can be achieved by orienting their windows to the south
- there is a return to the use of a heated crawl space to reduce building heave and protect water and heating services
- water and heating services are centrally grouped to minimize pipe runs and freezing problems
- an extra 3" of wall insulation has been added which allows outside wall electrical boxes and wiring to be placed inside the vapour barrier
- a continuous ceiling vapour barrier would be installed before inside walls are constructed
- underfloor insulation is included to reduce floor and header heat loss around the house perimeter
- the modified truss design will allow for more ceiling insulation
- access to the attic is via the gable end to eliminate leakage to the attic from the house through an inside access
- the programmable space heating thermostat will allow inside temperatures to be lowered at night

- better quality windows are specified which operate effectively in winter without breakage and are more energy efficient

- prehung insulated and weatherstripped exterior doors are specified

- pressure treated exterior wall, footing plate and cross beams are specified to prevent building twist and allow for adequate crawl space insulation.

Estimated Costs and Fuel Savings - Modified Versus Current Designs: Appendix H provides heat loss calculations for Lansdowne House comparing the modified design to the current design, and shows an estimated annual fuel savings of 1200 litres in the modified design. This represents a 40% fuel reduction.

The additional cost of building the modified design is estimated to be $5,000; this consists of an incremental $3,000 for materials and $2,000 for labour.

Based on the current fuel cost of 62¢/litre, the simple payback period is 6.7 years.

Recommended Action: It is recommended that the modified house design presented above and in Appendix G be used at Lansdowne House and it is recommended that contractors be asked to bid on the building to the specifications given in Appendix G, including the additional labour required to follow the specified building schedule. This would ensure that all prices would be compared on an equal basis. Installing a well sealed vapour barrier always takes slightly longer and its cost should not be compared with the conventional method of vapour barrier installation.

4.2.3 Super Energy Efficient Remote Airport House Design

In finalizing an energy efficient design for airport accommodation buildings built after Lansdowne House, further super energy efficient features warrant consideration. These are:

- condensing heating systems
- "curtain wall" construction
- air to air heat exchangers

A condensing heating system, reduces fuel consumption in two ways:

- furnace combustion efficiency is increased from 75% to 95%

- exfiltration losses which normally occur as a result of the chimney in a conventional furnace/-chimney installation are greatly reduced

"Curtain wall" construction, reduces fuel consumption by:

- allowing greater wall insulation levels to be used

- providing a practical construction technique that enables the installation and protection of a continuous vapour barrier

The incorporation of super energy efficient features such as condensing heating systems and "curtain wall" construction which greatly reduce natural air change in a building requires that some form of controlled ventilation be incorporated into house design to maintain acceptable levels of indoor air quality and moisture. An air-to-air heat exchanger provides the required ventilation without wasting a significant amount of heat. The heat that would otherwise be lost in the stale air drawn from the house is transferred in the heat exchanger to the incoming fresh air.

Each of the three features described above require some specific installer training. They are described in more detail below with specific examles given in Appedix I.

"Curtain-Wall" Construction: Curtain walls are constructed outside conventional 2 x 4 exterior load bearing walls of a building, usually "hung" from the eave as shown in Exhibit 4.6. This type of construction allows the vapour barrier to be attached to the outside of the main wall. This results in far fewer leakage points and enables all electrical and plumbing to be installed inside the vapour barrier. There is also less chance of puncturing the vapour barrier once it is installed. The building can be "closed in" before the curtain wall is built. A gap is left between the main wall and the 2 x 4 curtain wall so that a total of R36 insulation can be placed in the wall (R12 inside the vapour barrier and R24 outside). The R value for the completed wall is close to R40 (RSI7), much higher than can be obtained even with strapped 2 x 6 construction. Use of curtain wall construction also allows use of a separate outer "air barrier" -- a plastic wrap which allows moisture to pass through but not air.

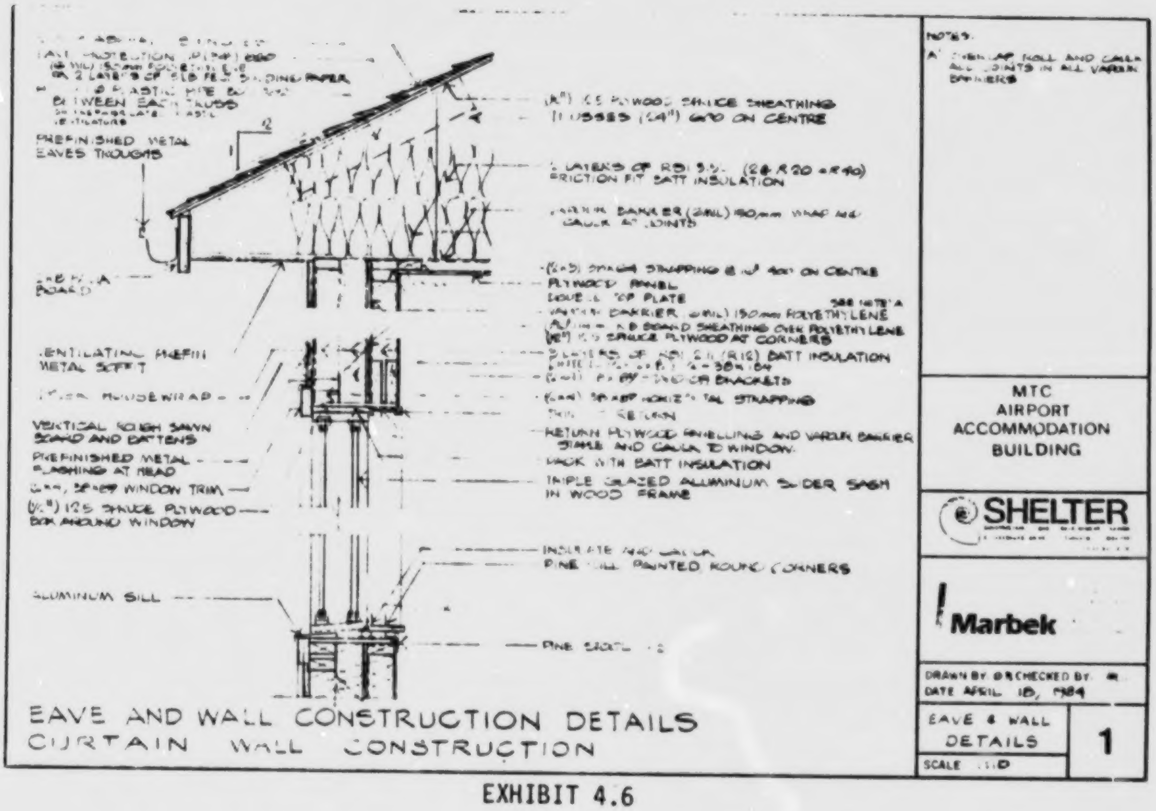

PREFINISHED METAL EAVES TROUGHS
BETWEEN EACH TRUSS
(⅜") 9.5 PLYWOOD SPRUCE SHEATHING
TRUSSES (24") 600 ON CENTRE
FRICTION FIT BATT INSULATION
VAPOUR BARRIER (6MIL) 150mm WRAP AND CAULK AT JOINTS
BOARD
PLYWOOD PANEL
DOUBLE TOP PLATE
SEE NOTE A
VAPOUR BARRIER (6MIL) 150mm POLYETHYLENE
(⅜") 9.5 SPRUCE PLYWOOD AT CORNERS
BATT INSULATION
VENTILATING PREFIN METAL SOFFIT
HOUSEWRAP
HORIZONTAL STRAPPING
RETURN
VERTICAL ROUGH SAWN BOARD AND BATTENS
PREFINISHED METAL FLASHING AT HEAD
WINDOW TRIM
BOX AROUND WINDOW
RETURN PLYWOOD PANELLING AND VAPOUR BARRIER STAPLE AND CAULK TO WINDOW.
PACK WITH BATT INSULATION
TRIPLE GLAZED ALUMINUM SLIDER SASH IN WOOD FRAME
INSULATE AND CAULK
PINE SILL PAINTED ROUND CORNERS
ALUMINUM SILL
PINE
EAVE AND WALL CONSTRUCTION DETAILS
CURTAIN WALL CONSTRUCTION
NOTES:
A OVERLAP ROLL AND CAULK ALL JOINTS IN ALL VAPOUR BARRIERS
MTC
AIRPORT
ACCOMMODATION
BUILDING
SHELTER
Marbek
DRAWN BY
CHECKED BY
DATE APRIL 18, 1984
EAVE & WALL DETAILS
1
SCALE

EXHIBIT 4.6

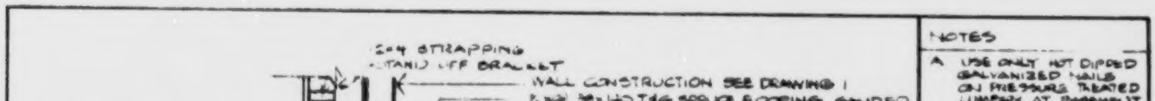

2x4 STRAPPING
STAND OFF BRACKET
WALL CONSTRUCTION SEE DRAWING 1
T&G SPRUCE FLOORING SANDED WITH 2 COATS OF URETHANE OVER PRIMER.
PINE WOOD BEAMS
FLOOR JOISTS
FINISHED FLOOR
TOP OF PLATE
BLOCKING TO HOLD COVER PANELLING
EXTEND VAPOUR BARRIER AROUND END OF BEAM
BUTTRESSING RING PLATE (2x4) 38x89
EXTEND PANELING
SINGLE TOP PLATE NOTE ALL BEAMS TO BEAR DIRECTLY OVER STUD
NOTE MINIMUM BEAM BEARING (3½") 89
INTERIOR PLYWOOD PANELS
VAPOUR BARRIER 6MIL POLYETHYLENE
R28 RSI 4.9 BATT INSULATION
2x8 38x184 PRESSURE TREATED STUDS AT 16" ON CENTRE SEE NOTE 'A'
(⅝")15.9 PRESSURE TREATED PLYWOOD
WIDE STRIP OF PRESSURE TREATED PLYWOOD AT GRADE
7'-5"
BITUMEN COATING (EMULSIFIED ASPHALT)
(6MIL) 150mm POLYETHYLENE
4" 100 Φ PERIMETER DRAINAGE
FREE DRAINING BACKFILL
PRESSURE TREATED (2x8) 38x184 PLATE ON 2x10 38x235 PRESSURE TREATED FOUNDATION PLATE
6MIL (150mm) POLYETHYLENE
PRESSURE TREATED (⅝") 15.9 PLYWOOD
1" R5 STYROFOAM INSULATION
(2x6) 38x140 PRESSURE TREATED FLOOR FRAMING (16") 400 ON CENTRE
(2x4) 38x89 PRESSURE TREATED SLEEPERS
(6") 150 CRUSHED STONE BASE
FIN.FL.
BASEMENT WALL DETAILS (SIDE)
CURTAIN WALL CONSTRUCTION
NOTES
A USE ONLY HOT DIPPED GALVANIZED NAILS ON PRESSURE TREATED LUMBER AT BASEMENT SEE SPECIFICATION FOR GRADE OF PRESSURE TIMBER TREATMENT
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
SHELTER
Marbek
DRAWN BY. OP CHECKED BY.
DATE. APRIL 18 1984
WALL DETAIL FOR BASEMENT
2
SCALE. 1:10

EXHIBIT 4.7

Exhibits 4.6 and 4.7 show the detailing of windows in a curtain wall and the way in which a pressure treated wood foundation wall is built. Curtain wall construction will increase the cost of building a house by a small percentage but will result in a much tighter house (lower infiltration rates) and reduced wall heat losses due to the increased insulation levels. Many super energy efficient houses using this type of construction have air change rates as low as 0.05 per hour.

In comparison to the Modified House Design, presented in Section 4.2.2, the further reduction in air infiltration and increased wall thermal resistance resulting from incorporating the "curtain wall" method of construction is estimated to reduce fuel consumption by about 450 l/yr or $280/yr at a 62¢/l fuel price.

Condensing Heating Systems: In conventional fossil fuel burning heating systems up to 45% of the heat produced is lost in the combustion gases. The requirement for a chimney also means that special provisions must be made in an air tight energy efficient house to seal around the hot pipe where it passes through the vapour barrier and to allow sufficient combustion air into the house. In a condensing heating system the combustion gases are cooled with a liquid (usually water) so that the previously lost heat is transferred to the liquid and any corrosive liquids or tar particles usually present in the combustion gases are removed (condensed). The result is over 90% combustion efficiency and replacement of the hot chimney with a plastic vent pipe and small drain. In an air tight energy efficient house this means simpler air sealing provisions around the vent pipe and the handling of all ventilation and combustion air with an air to air heat exchanger. The result is even lower heat losses through infiltration in addition to the higher fuel efficiency.

Until recently, only condensing heating systems designed for use with natural gas were available, and in sizes too large for the small heating requirements of energy efficient housing. It is now possible, however, to buy Canadian made condensing heating systems which will burn propane or oil and also supply domestic hot water as well as space heat. Propane units are available with ratings starting at 40,000 Btu/hr, and oil units with ratings starting at 80,000 Btu/hr.

An example of a condensing oil/propane boiler system which can provide both warm air for heating and domestic hot water is shown in Appendix I. This particular unit also has the advantage, over conventional heating systems, of requiring zero clearance. It could be installed in a closet, storage room, or crawl space. These units typically cost about $3,500 retail or about $1,000 more than the cost of separate oil fired warm air furnace and prepare hot water heater. The fuel efficiency improvement alone, from 70% to 95%, would reduce annual fuel consumption by 25%. Assuming an annual combined space and water heating load of 16,000 kWh/year for an energy efficient MTC airport house, this would mean an annual fuel saving of 565 litres per year, worth $350 at 62¢/litre. The condensing heating system would therefore pay for itself in 3 years, not counting the reductions in heat load because of lower air infiltration or the reduced chimney costs.

Air to Air Heat Exchanger: Controlled ventilation is becoming an important feature in all new housing, energy efficient or not. The recent concerns over radon gas and UFFI in homes built to conventional standards will soon lead to mandatory requirements for controlled ventilation in new buildings to maintain air quality in the building and prevent high humidity levels. This controlled ventilation can be obtained without significant heat loss by using air-to-air heat exchangers. House air, usually drawn from high humidity areas such as the kitchen and bathroom vents, is discharged through the heat exchanger which transfers the heat in the outgoing air to fresh incoming air. The incoming air usually flows into the basement or crawl space where it mixes with circulating house air.

Various types of heat exchangers are on the market. Each uses different methods to exchange heat between the two air streams. Examples of three types are:

- plastic core "plate type" exchangers in which the air streams are blown through adjoining but separated plastic honeycombs

- rotary or capillary blower exchangers in which a continuously turning wheel is heated by the outgoing air stream and then heats the incoming air stream

- heat pipe type exchangers in which the boiling end of heat pipes extract heat from the outgoing air stream and the condensing end of the heat pipes heat incoming air.

Several examples of Canadian made heat exchangers are given in Appendix I. These exchangers should be installed by experienced personnel so that they do not interfere with the supply of combustion air and the incoming and outgoing air streams are properly balanced.

Controlled ventilation without air heat exchange can result in significant heat losses and increased fuel consumption. Air to air heat exchangers have an average effectiveness of 60-75% and cost in the region of $1,000 to $1,500.

Recommended Action: Following the construction of the new Lansdowne House accommodation building to the modified design described in Section 4.2.2, it is recommended that MTC develop an energy efficient universal design for all future airport houses based on the modified Lansdowne House design but incorporating some or all of the above additional features. The universal design could be developed with assistance from personnel with experience in energy efficient design and construction. Information and training sessions on energy efficient building techniques should be held during 1984/85 so that buildings can be built to the universal design starting in 1985.

4.3 NEW GARAGES FOR MTC REMOTE AIRPORTS

4.3.1 Background

MTC is planning to build several new airports in Northern Ontario communities over the next 5-10 years. Each new airport will require a garage for equipment storage and repair.

The garage is typically the first building erected at a new airport site and must be constructed from materials that can easily be transported to the site. This places several restrictions on the type of materials and components (eg, doors) that can be used. As described previously, garages at existing airports are usually of wood frame construction with plywood interior and exterior sheathing. The main doors are also built on-site and open on a simple horizontal track.

There are two features of MTC airport garages which mitigate against the use of more airtight sectional overhead doors in place of the sliding doors now in use. One is the fact that the door must be assembled on-site because of shipping restrictions. The other is the limited headroom in the garages. The height of the garage would have to be extended by 2/3 feet to allow storage of an overhead door and easy access for airport graders. This would involve extensive redesign of the garage and increased costs. The proper use of weatherstripping and the existing sliding door design should reduce infiltration losses to an acceptable level while also offering resistance to transmission losses when closed.

In Section 3.3 it was shown that existing garages can be thermally upgraded for a relatively small expenditure. The addition of door weatherstripping, automatic thermostats, and retention head burners were estimated to reduce fuel costs by 60% with an overall pay back of less than 1 year.

In new garages there are opportunities to reduce fuel costs even further:

- Building a new garage to increased levels of wall and ceiling insulation would be less costly than retrofitting the walls and ceiling in an existing garage

- Always siting the garage in the direction which minimizes wind induced infiltration would minimize fuel costs at no additional cost

- The use of more effective warm air distribution equipment in the garage would allow inside temperatures to be maintained at lower levels without loss of comfort

- Finally, the installation of the airport power generator with waste heat recovery in the garage when it was built would almost eliminate any residual heating requirements

Each of the above energy efficient features is discussed below.

4.3.2 Energy Efficient Features for New Garages

Door Weatherstripping: The same type of weatherstripping suggested for existing garage doors in Section 3.3 could be used in new garage doors, except that the on-site construction technique would be modified slightly so that the special channels for the brush type weatherstripping could be attached during construction of the doors. More attention could also be given to ensuring that the doors and door openings were square so that crack areas were minimized.

Automatic Thermostat: In new garages with waste heat recovery and a conventional back-up forced air furnace, the thermostat would be used to control both the waste heat recovery system delivery damper (see below) and the back-up furnace. If an overhead destratifying distribution system were used (see below), the thermostat could be set so that the damper was controlled to maintain the garage at 10°C and the back-up unit was turned on only when the daytime temperature dropped below, say, 8°C and the nighttime temperature below 4°C. It was shown in Section 3.5 that the waste heat recovery system on its own could maintain inside temperatures above 10°C at all times when the outside temperature is above -23°C.

Retention Head Burner: The back up furnace installed in a new garage could be purchased with a retention head burner in place. The additional cost would be less than the $500 retrofit which itself was shown to have a payback of less than a year. A retention head burner can be excpected to have a fuel efficiency of 75%.

Increased Wall and Ceiling Insulation Levels: In Section 3.3 it was shown that adition of styrofoam insulation to the side walls of existing garages was not cost effective. In new garages, increasing wall insulation levels would involve far less cost. Using 2 x 6 construction in all walls and the sliding doors instead of 2 x 4 would increase wall framing materials costs by only about $300 (assuming 16" centres). Lower cost fibreglass insulation could be used instead of styrofoam and there would be no increase in labour costs. Ceiling fibreglass insulation levels could be doubled (and heat losses halved) for an additional $500 of insulation. Insulation levels would then be RSI 3.8 (R22) for the walls and RSI 7.3 (R42) in the ceiling.

Siting the Garage for Minimum Infiltration: In Section 3.3 it was shown that infiltration losses through both closed and open garage doors are dependent on the direction in which the doors face. At Bearskin Lake, the door facing SW was estimated to lose about 20% less heat than the door facing NE (assuming the same door opening schedule). To minimize infiltration, the garage should be sited such that the infiltration losses are a minimum. Assuming that wind data for Big Trout Lake is representative with respect to direction, duration, and actual speed, for all Northern Ontario communities, minimum infiltration losses will occur if the doors face in a direction where windspeed and duration from the 5 contributing directions (see Appendix B) during the heating season is a minimum (subject to the limitation that the two doors must face in opposite directions). From Canadian Wind Normals, this minimum occurs if the doors face NE and SW. The smallest of the two infiltration losses using this siting arrangement will be through the SW door. The airport should be laid out in such a way that the SW garage door is the most frequently used door during winter operations.

More Effective Air Distribution/Ventilation System: Many commercial warehouses now utilize a forced air distribution/ventilation system which is specifically designed to destratify the air in buildings with high ceilings. The units have perforated plastic ducts which run the length of a building close to the ceiling. Warm air is forced down into the heated area preventing any stratification and quickly heating cold areas when doors are opened. If needed, a controlled amount of fresh air can be introduced to maintain adequate ventilation. The result is that a lower temperature setting can be used because the occupants feel more comfortable and less heat accumulates in ceiling areas.

The overhead distribution ducts replace conventional floor or work area distribution systems. This increases valuable work space and reduces costs. A distribution system of this type would also be very effective in maintaining an even temperature when heating is provided from two sources - waste heat recovery and a back-up furnace.

In a new garage, where headroom is limited, a distribution duct could be suspended along the top of one wall. One duct would distribute warm air from both the power system waste heat recovery unit (see below), and from the back-up furnace. The cost of the flexible ducting is about $15 per metre.

Waste Heat Recovery System: In Section 3.5 it was recommended that permanent 15kW power systems with waste heat recovery be installed in existing garages where there would be several years delay before connection to community power. At new airports, the value of installing a power system in the garage would be even higher. The installation cost would be lower than for the retrofit case because the garage could be built with the walls appropriately placed and the recovery system ducting in place, rather than having to remove an existing furnace and add new walls. Because the garage and power system are the first facilities to be built at an airport, the time period over which savings would be obtained would also be longer than in a retrofit situation.

In a new garage, the diesel generator and heat recovery system could be built in one unheated outside bay, with a single forced air furnace (with retention head) in the other unheated bay. A suggested power system layout and specifications for a 15 kW power system, waste heat recovery system, and controls is presented in Appendix D.

4.3.3 Estimated Energy Consumption and Costs

Table 4.1 presents an energy balance for a new MTC airport garage which incorporates the energy conserving features discussed above in Section 4.3.2. As shown in Table 4.1, the estimated annual fuel consumption is about 4,090 litres. At the current fuel price of 62¢/litre, this is equivalent to about $2,535/year. In contrast, IA Section 3.3 it was estimated that current airport garages consume 14,600 litres annually, for an average expenditure of $9,050. Consequently, annual savings are estimated to be about 10,500 litres or about $6500 per year.

TABLE 4.1
ENERGY BALANCE FOR NEW ENERGY EFFICIENT GARAGE FOR MTC AIRPORTS

Inside design temperature: 6°C (8°C day, 4°C night)
Outside Design temperature: -38°C (Ground 2°C)
Degree Days below 6°C: 4,000
Siting: NE/SW

BUILDING COMPONENT	RSI VALUE	AREA m^2	T °C	DESIGN HEAT LOSS Watts	ANNUAL HEAT LOSS kWh/yr
Walls	3.8	200	44	2,320	5,100
Ceiling	7.3	130	44	780	1,700
Doors	3.8	35	44	410	900
Floor	0.7	130	4	740	1,600
				4,250	9,300
Infiltration (door air gap 0.1%)					23,200
Total:					32,500
Fuel consumption at 75% burner efficiency					4,090 l/yr
Fuel cost at 62¢/litre					$2,535/year

As shown in Table 4.2 the estimated additional construction cost is about $3,200; consequently, the payback period is about 6 months.

TABLE 4.2
ESTIMATED ADDITIONAL COSTS OF ENERGY EFFICIENT FEATURES FOR NEW MTC AIRPORT GARAGES

	Materials	Labour	Total
Door Weatherstripping	$ 400	$ 300	$ 700
Extra Wall and Door Insulation	$ 700	-	$ 700
Extra Ceiling Insulation	$ 500	-	$ 500
Automatic Thermostat	$ 200	-	$ 200
Retention Head Burner	$ 300	-	$ 300
Siting for Minimum Infiltration	-	-	-
Improved Air Distribution	$ 500	$ 300	$ 800
TOTALS:	$2,600	$ 600	$3,200

4.3.4 Recommended Actions

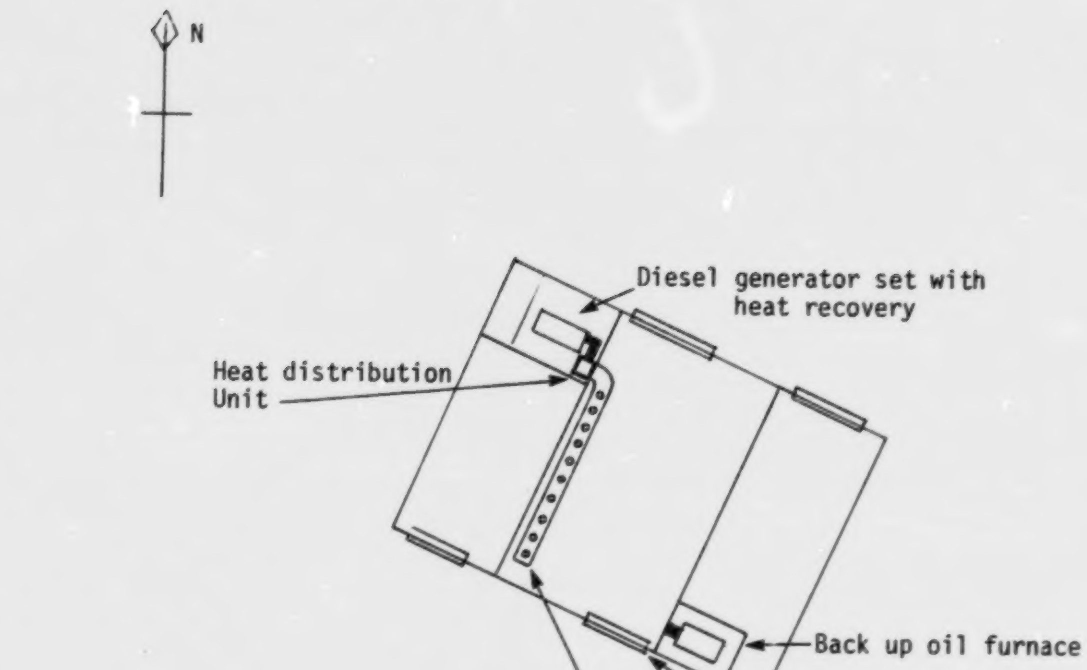
It is recommended that all new equipment garages at new MTC airports in Northern Ontario be built with the following features:

- The garage be built to current design except that all walls surrounding the heated central bay be of 2x6 construction insulated to RSI 3.5 (R20), and ceiling insulation be RSI 7.0 (R40).
- Sliding exterior doors to the heated bay be fitted with pile type weatherstripping as described in Section 3.
- Heating be provided by a combination of waste heat recovery from the airport electric power generator as described in Section 3.5, a single forced air furnace, and a destratification warm air circulation/ventilation system installed at ceiling level.
- A programmable space heating thermostat be used that can control both the waste heat recovery air flow damper and the oil heating system. The oil heating unit would only be called upon when there was insufficient waste heat to maintain a comfortable temperature. The waste heat damper would be the primary control to maintain temperatures within the set range.
- The garage be sited at the airport such that the doors face NE and SW, and the door facing SW be the one most commonly used during the heating season.

A suggested plan and siting arrangement developed by the Study team for new MTC airport garages is shown in Exhibit 4.8.

EXHIBIT 4.8

PLAN AND SITING ARRANGEMENT FOR NEW MTC AIRPORT GARAGE


N
Diesel generator set with heat recovery
Heat distribution Unit
Back up oil furnace
Air distribution duct
SW facing door most frequently used
office/accomodation building (office and kitchen facing south) (see Section 4.2)

4.4 NEW WAITING ROOMS FOR MTC REMOTE AIRPORTS

4.4.1 Background

In Section 3.4 it was shown that with minimal thermal upgrading, the fuel consumption in airport waiting rooms could be cut by two-thirds to 1200 l/yr or $700/yr. In new waiting rooms however, further reductions in fuel consumption could only be achieved if a different method of heating were used. A small oil stove has a minimum setting below which it cannot be adjusted. Reducing the design heat loss of the waiting room below 2300 watts would simply increase the space temperature.

The only way of meeting a design heat load of less than 2300 watts would be to use electric heaters. Assuming 5000 degree days below 10°C, the amount of electricity required to meet a 2300 watt design load would be 6000 kWh/yr. At an airport with power costing 50¢/kWh from community power, it would cost about $2,700/yr to heat the waiting room. However, if the electric heaters were used only when needed, the cost would be much lower and would probably be less than for oil heating. The heaters could be controlled from the airport office, and a timer could be installed to ensure that the power was not left on unnecessarily.

4.4.2 Energy Efficient Features for New Waiting Rooms

To minimize heat losses when the waiting room is used, it would be appropriate to use 2 x 6 construction in new waiting rooms instead of 2 x 4 and to increase insulation levels to RSI 3.5 (R 20 fibreglass) in the walls, RSI 7.0 (R40 fibreglass) in the ceiling, and RSI 1.7 (R 10 styrofoam) in the floor. Prehung, preinsulated doors, with good weatherstripping could be used. If electric heating were used, then the most suitable type would be fan coil units to provide fast warm up of the space.

4.4.3 Estimated Costs and Savings

The estimated additional cost of the measures described in Section 4.4.2 would involve only increased materials costs; construction time would be unchanged from the present waiting room design. The additional materials costs are estimated to be as follows:

Doors	$ 300
Insulation	$ 400
Lumber (16" centres)	$ 50
Heating Systems and Controls	$ 250
Total:	$1,000

Table 4.3 gives the estimated energy balance for a new energy efficient waiting room with intermittent electric heating.

TABLE 4.3

ENERGY BALANCE FOR ENERGY EFFICIENT AIRPORT WAITING ROOM

Inside design temperature: 10°C
Outside design temperature: -38°C
Degree days below 10°C: 5,000

BUILDING COMPONENT	RSI VALUE	AREA m^2	T °C	DESIGN HEAT LOSS Watts
Walls	3.8	40	48	510
Ceiling	7.3	20	48	130
Floor	2.2	20	48	440
Windows	0.7	3	48	210
Doors	0.7	4	48	270
				1560
Infiltration (0.5 air changes per hour)				250
				1810
Annual heat loss (assuming 20% usage):				905 kWh/yr
Annual heating cost at 48¢/kWh:				$430

In contrast to the existing waiting room fuel costs shown in Section 3.4, the reduction in fuel costs is \$2,100 - \$430 = \$1,680/year for an additional investment of only \$1,000. The design heat loss of 1810 watts could be handled by two 1 kW fan coil electric heaters.

4.4.4 Recommended Action

All new MTC airport waiting rooms should be of 2 x 6 construction with the following insulation levels:

Walls	RSI 3.5
Ceiling	RSI 7.0
Floor	RSI 1.7

Preinsulated and preweatherstripped wood doors should be used.

Electric fan coil heating should be installed, consisting of 2 x 1 kW heating units. Thermostats, set at 10°C and controlled from the airport office and the waiting room itself, should have an automatic timer to shut off the heaters after 2 hours operation.

SECTION 5

WINISK AIRPORT FACILITIES

5.1 INTRODUCTION

The airport facilities at Winisk were built in the 1950s for Department of National Defence. They have been adapted by MTC for use as the civilian airport for the local community. The main building is a large hanger approximately 40m wide, 30m long and 12m high. Two single storey wings are built along each side of the hangar. One wing houses the power generation system and workshop. The other wing contains a small hotel consisting of a number of bedrooms, a bathroom, kitchen, dining room, and office. A small enclosed garage has been built inside the hangar adjacent to the power generator room. Two small extensions, to enlarge the dining room and enclose a fire protection water tank, have been built inside the hangar adjacent to the hotel wing. A small self-standing 6m x 9m single storey house is attached to the hotel wing. This is occupied by the airport manager. The only other MTC building is a small 6m x 6m waiting room. The diesel power generators are operated by ONTC and supply power to the workshop, garage, hotel, house, waiting room, ONTC Telsat communications system, runway lights, and aircraft beacon. The whole complex was once heated from a steam boiler which has since been removed.

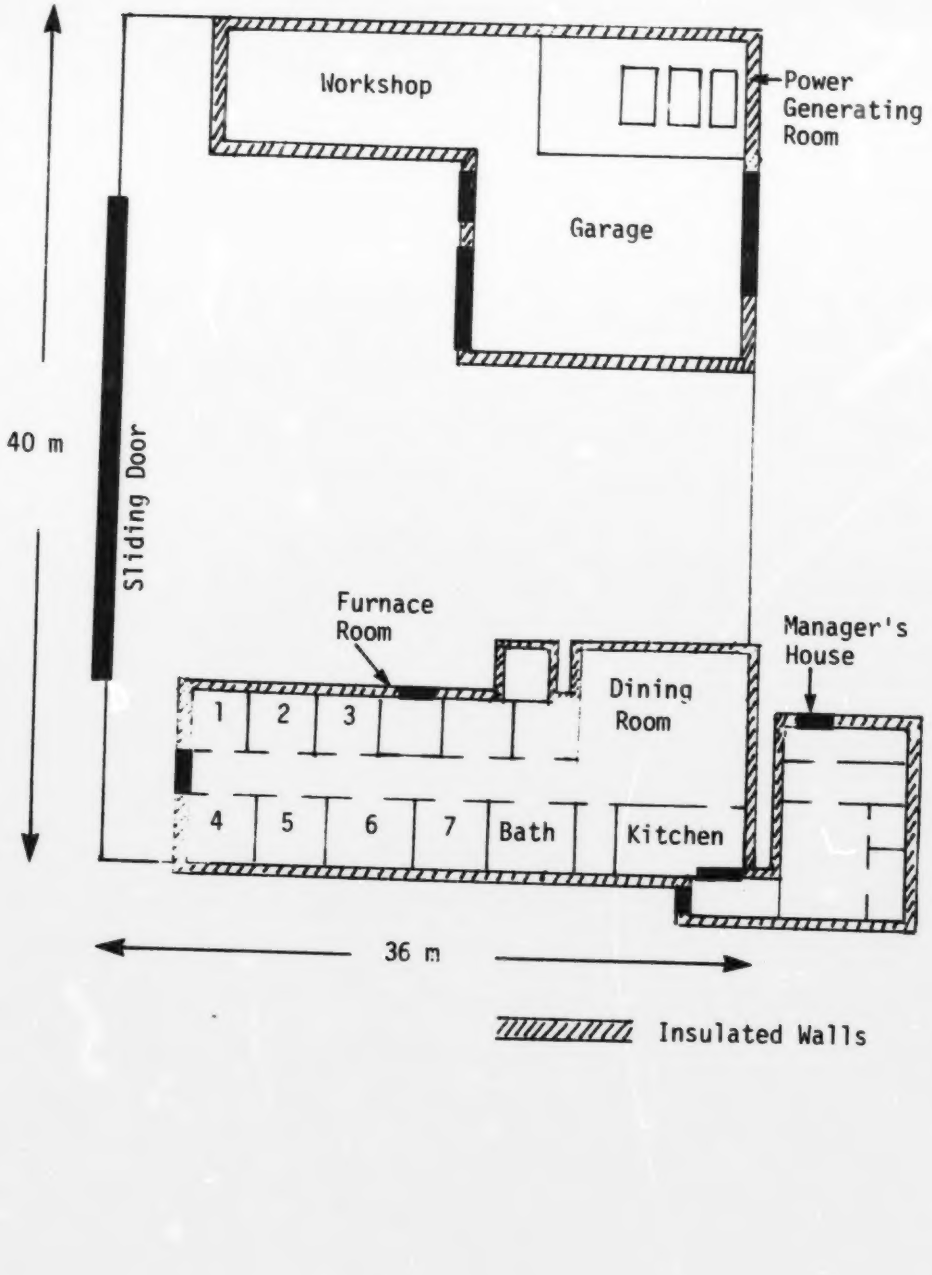
A floor plan of the main airport building and house is shown in Exhibit 5.1. Exhibit 5.2 is a picture of the Winisk airport hangar.

Energy consumption in the airport hotel, manager's house, and waiting room is addressed in Sections 5.2, 5.3, and 5.4. The ONTC power system is discussed in Section 5.5, including an analysis of the option of adding a wind turbine to reduce fuel consumption.

EXHIBIT 5.1

WINISK HOTEL/HOUSE

Floor Plan


Workshop
Power Generating Room
Garage
40 m
Sliding Door
Furnace Room
Manager's House
Dining Room
1
2
3
4
5
6
7
Bath
Kitchen
36 m
Insulated Walls

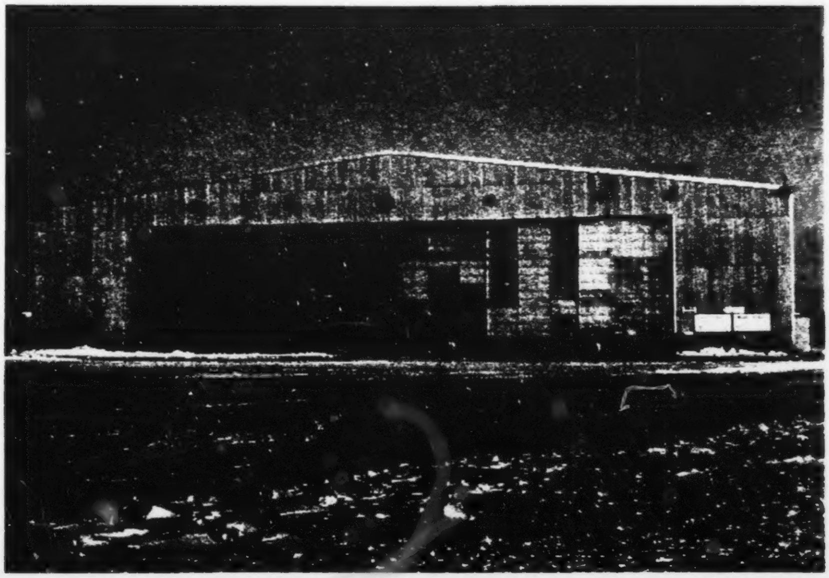


Exhibit 5.2: WINISK AIRPORT HANGAR

5.2 WINISK AIRPORT HOTEL

5.2.1 Description

The hotel portion of the airport building is wood frame built inside steel framing. Walls are 2 x 4 construction with 2" strapping covered with plywood and insulated to approximately RSI 3.5. The ceiling has 4" fibreglass insulation over a partial vapour barrier with a finish of acoustic tiles over plywood, except over the dining room extension which has 6" fibreglass insulation. Additional insulation (6" batts) is currently being placed over the ceiling. The floor is vinyl tiles over a concrete slab. Windows are double vertical sliding metal framed units. Doors are solid wood in wood frames. The building is heated by a Preston OL280HB-23-1-RH hot air oil furnace with two circulating fans each distributing hot air to a different end of the wing. Hot water is provided by 2 Rheem electric water heaters. All water lines are above grade; some run through ceiling and wall insulation. This had led to occasional water pipe freeze-up and water damage.

Air leakage in the hotel is quite low. The windows are well sealed, and the strapped walls provide some reduction in infiltration. Infiltration occurs mainly through doors. Exfiltration occurs through the ceiling, particularly in the dining room extension which has a poorly sealed vapour barrier in some places and no vapour barrier in others. During the site visit the interior temperature varied between 18°C and 20°C. A design interior temperature of 18°C was used.

Electrical consumption in the hotel is mainly for lights (2.5kW), appliances (3kW), furnace (1kW) and water heaters (4.5kW).

5.2.2 Current Fuel Consumption and Costs

A summary space heating energy balance for the Winisk airport hotel is given in Table 5.1. The detailed calculations are given in Appendix J.

As shown in Table 5.1, the annual space heating load is approximately 78,200 kWh. Assuming a 65% average oil furnace efficiency and a heating value of 10.6 kWh/litre, the estimated annual fuel consumption is 11,400 litres/year. At the current on-site fuel cost of $1.05/litre, this is equivalent to about $12,000/year.

5.2.3 Retrofit Measures

The site visit and energy audit of the MTC hotel at Winisk showed that, in general, outside walls, doors, and windows were in reasonably good condition. Infiltration was found to be quite low and insulation levels adequate. The main problems appear to be in the attic space. There are relatively low levels of insulation in the ceiling, though more is being added, and there is a chronic problem of pipes freezing and bursting in the attic space. The small addition built out into the hangar to house the extended dining room has also suffered water damage from burst pipes. The pipes run through the attic space to serve the kitchen and manager's house. As it is not possible to run them through the concrete floor slab, the only options available to prevent the freezing are to re-route all attic pipes along the inside of the hotel walls or to

TABLE 5.1

WINISK AIRPORT HOTEL

SPACE HEATING ENERGY BALANCE

Design temperatures: - 38°C (-36°F) exterior
2°C (36°F) ground
18°C (65°F) interior

Degree Days: 8600 below 18°C

Building Component	RSI Value	Area m^2	T °C.	Design Watts	Annual Heat Loss kWh/yr
Walls	3.8	130	56	1920	7,100
Ceiling	3.7	220	56	3330	12,300
Floor	0.8	220	16	4400	16,200
Doors	0.7	6	56	480	1,800
Windows	0.7	24	56	1920	7,100
				12,050	44,500
Infiltration (0.75 air changes per hour)				9,150	33,700
		TOTAL:		21,100	78,200

Annual Fuel Load (65% burner efficiency)
= 11,400 litres/year (2175 gal/year)

box in the pipes in the attic and cover them with insulation. In this way, the pipes would be surrounded by warm air from the heated space.

The energy audit and site visit also showed that the vapour barrier in the attic and the ceiling of the dining room extension was not adequate, and is probably one of the reasons why the pipes freeze. Heat losses through infiltration could be reduced by installing a completely new vapour/air barrier over the heated space. Up to R40 insulation could then be placed in the attic without the risk of condensation in the insulation.

Given that extensive thermal upgrading needs to be done in the attic space, it is recommended that the pipes be left in the attic and boxed in at the same time that a new vapour barrier is added. The following procedure would reduce heat losses and protect water piping:

- Remove all attic insulation and vapour barrier over main hotel wing and remove insulation over the dining room extension.

- Heavily insulate the water pipes supplying the manager's house between the hotel and the house.

- Install aspenite sheathing or equivalent over the joists in the main hotel wing attic, and cover with a new continuous polyethylene vapour barrier.

- Seal any gaps in the vapour barrier between the joists over the dining room extension, adding new vapour barrier as necessary and sealing any gaps between the dining room extension and new vapour barrier added over the main wing.

- Install R40 (RSI 7.0) insulation in the main wing attic over the aspenite sheathing and vapour barrier.

- Install 2 x 3 strapping on the ceiling joists over the dining room extension.

- Install R30 (RSI 5.2) insultion between the strapped joists over the dining room extension and cover with aspenite sheathing or equivalent.

In addition to the above work, heat losses could also be reduced by installation of an automatic night set back thermostat (to say 12°C (55°F)) and replacement of the current furnace burner with a retention head burner (see also sections 3.2 and 3.3)

5.2.4 Estimated Retrofit Costs and Savings

The total cost of implementing the above retrofit measures is estimated to be about $5,500. The cost of replacing the attic insulation and vapour barrier, as described above, is estimated to be about $2,550 for materials ($1,800 insulation/lumber + $750 freight) and $2,250 for labour (150 hrs @ $15/hr). The cost of the automatic thermostat would be about $200 installed, and the retention head burner about $500 installed.

Attic Retrofit: Table 5.2 shows that the estimated annual fuel savings from replacing the attic insulation is about 1960 litres. This assumes a night set back temperature of 12°C and the installation of a retention head burner with 75% efficiency. The cost savings, assuming a local fuel price of $1.05/litre, would be $2,000. The simple payback is therefore about 2½ years.

TABLE 5.2

ESTIMATED SAVINGS RESULTING FROM ATTIC RETROFIT IN WINISK AIRPORT HOTEL

Reduction in ceiling transmission losses (50%)	6,150 kWh/yr
Reduction in infiltration losses (0.75 to 0.5 air changes/hr)	11,200 kWh/yr
Total reduction	17,350 kWh/yr
Total reduction after use of set back Thermostat (see Table 5.3)	15,600 kWh/yr
Fuel savings assuming 75% burner efficiency	1,960 l/yr
Cost savings @ $1.05/litre	$ 2,058/yr

Automatic Thermostat: As shown in Table 5.3, the installation of an automatic set back thermostat is estimated to reduce annual fuel consumption by 780 litres/year. This reduction assumes that the ceiling retrofit measures (above) have been implemented and that (on average) an interior temperature of 12°C is maintained for 50% of the time (ie, 10 hrs/day during the week and longer on weekends when the hotel is often vacant). At $1.05/l annual savings would be $820 for a simple payback of less than 3 months.

TABLE 5.3

CALCULATION OF NIGHT SET BACK HEAT LOSS REDUCTION

Time averaged interior temperture: 15°C

Current interior temperature : 18°C

Average outside temperture : - 12°C

Reduction Factor: $\frac{(15-(-12))}{(18-(-12))}$ = 0.9

Building Heat Losses after ceiling retrofit (from Table 5.2) = 61,850 kWh/yr

Reduction in heat losses from using thermostat : 6,200 kWh/yr

Fuel savings @ 75% burner efficiency : 780 l/yr

Retention Head Burner: The building heat loss after ceilng retrofit and addition of the automatic thermostat will be (from Table 5.3) 55,650 kWh/yr. Assuming that the retention head burner improves fuel efficiency from 65% to 75%, then the fuel savings will be equal to:

$$\frac{55,650}{10.6}\left\{\frac{1}{0.65} - \frac{1}{0.75}\right\} = 1080 \text{ l/yr}$$

At $1.05/l, this is worth $1130/year. Given an installed cost of about $500, the simple payback is less than 6 months.

5.2.5 Recommended Action

Since all the above measures have very fast paybacks it is recommended that they be carried out as a complete retrofit package. The hotel energy balance after retrofit is given in Table 5.4. Overall reduction in fuel consumption is 4,500 l/yr which is worth $4,700 at a $1.05/l fuel price. Overall cost of the retrofit is estimated to be $5,450 for a simple payback of just over 1 year.

TABLE 5.4

WINISK HOTEL ENERGY BALANCE
POST RETROFIT

Building Component	Heat Losses
Wall	6,400 kWh/yr
Ceiling	5,500 kWh/yr
Floor	4,600 kWh/yr
Doors	1,600 kWh/yr
Windows	6,400 kWh/yr
Infiltration	20,250 kWh/yr
Total	54,750 kWh/yr
Fuel consumption @ 75% fuel efficiency	6,900 l/yr

5.3 WINISK AIRPORT MANAGER'S HOUSE

5.3.1 Description

This 6m X 9m single storey wood frame house is attached to the hotel wing of the airport complex. It was built about the same time as the original hangar (around 1955) and is of 2 X 4 construction with an extra 2" strapping on the interior with an effective 6" insulation. The floor is 2 X 4 wood frame over an unheated crawl space. The ceiling and floor cavities are inaccessible but probably have about 10 cm. of old insulation. Doors are solid wood with wood frames. Windows are double vertical sliding wood framed units. The building is heated with a Grimsby 67.167C. forced air furnace rated at 173,000 Btu per hour. The warm air and return ducts are mounted on the outside of the interior walls with overhead distribution because of the unheated crawl space. This creates a dangerous obstruction and results in uncomfortably cold floors. Water is supplied from the hotel through an outside above-grade pipe which often freezes. The building is generally very leaky and uncomfortable.

Electrical consumption in the house is mainly for lights, small appliances, stove, and furnace fan. The estimated maximum load is about 4kW

5.3.2 Current Fuel Consumption and Costs

A summary space heating energy balance for the Winisk airport manager's house is given in Table 5.5. The detailed calculations are given in Appendix J. Design interior and exterior temperatures and degree day values below 18°C used in the calculation were the

same as those used in the hotel energy balance.
As shown in Table 5.5, the annual space heating load is approximately 29,500 kWh. Assuming a 65% average oil furnace efficiency and a heating value for fuel oil of 10.6 kWh/litre, the estimated annual fuel consumption is 4300 litres. At the current on-site fuel cost of $1.05/litre, this is equivalent to $4500/year.

5.3.3 Retrofit Measures

The site visit and energy audit showed that the Winisk manager's house is uncomfortable, cramped, and unsafe (exposed ducting presents dangerous obstructions). The house costs $4500 per year to heat, and often has no water during the winter.

Although discussions are underway with respect to relocating the community of Winisk, the Study Team was assured that the present airport facilities will remain at their current location and will continue to be maintained. Therefore, given the current poor condition of the manager's house, it is recommended that a new house be constructed rather than attempt to renovate the present one.

Two energy efficient designs for a new Winisk airport manager's house developed by the Study Team are given in Exhibits 5.3 and 5.8 through 5.11. Proposal #1 has a half basement and uses the super energy efficient curtain wall construction described in Section 4. Proposal #2 has a heated crawl space and uses a simpler strapped wall construction.

TABLE 5.5

WINISK AIRPORT MANAGERS HOUSE
SPACE HEATING ENERGY BALANCE

Design temperatures: -38°C (-36°F) exterior
18°C (65°F) interior

Degree Days: 8600 below 18°C

Building Component	RSI Value°	Area m^2	T °C.	Design Heat Loss Watts	Annual Heat Loss kWh/yr
Walls	3.8	66	56	970	3,600
Ceiling	2.4	54	56	1260	4,600
Floor	2.4	54	56	1260	4,600
Windows	0.7	7	56	560	2,100
Doors	0.7	2	56	160	600
				4210	15,500
Infiltration (1.5 air changes per hour)				3800	14,000
		TOTAL:		8010	29,500

Annual fuel load (65% burner efficiency)
= 4300 litres/year

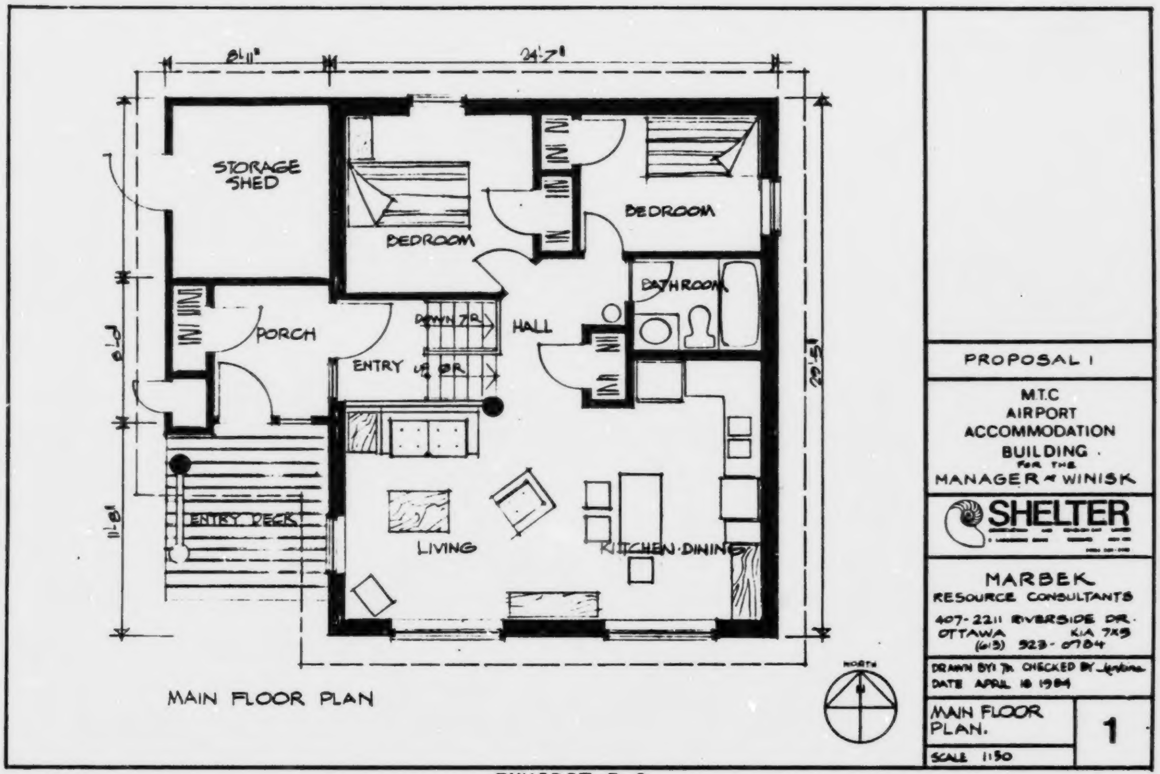

8'-11"
24'-7"
29'-5"
9'-0"
11'-8"
STORAGE SHED
BEDROOM
BEDROOM
BATHROOM
HALL
DOWN 7R
PORCH
ENTRY
UP 8R
ENTRY DECK
LIVING
KITCHEN · DINING
NORTH
MAIN FLOOR PLAN
PROPOSAL 1
M.T.C
AIRPORT
ACCOMMODATION
BUILDING
FOR THE
MANAGER AT WINISK
SHELTER
MARBEK
RESOURCE CONSULTANTS
407-2211 RIVERSIDE DR.
OTTAWA K1A 7X5
(613) 523-0784
DRAWN BY: TR CHECKED BY
DATE APRIL 10 1984
MAIN FLOOR PLAN.
1
SCALE 1:50

EXHIBIT 5.3

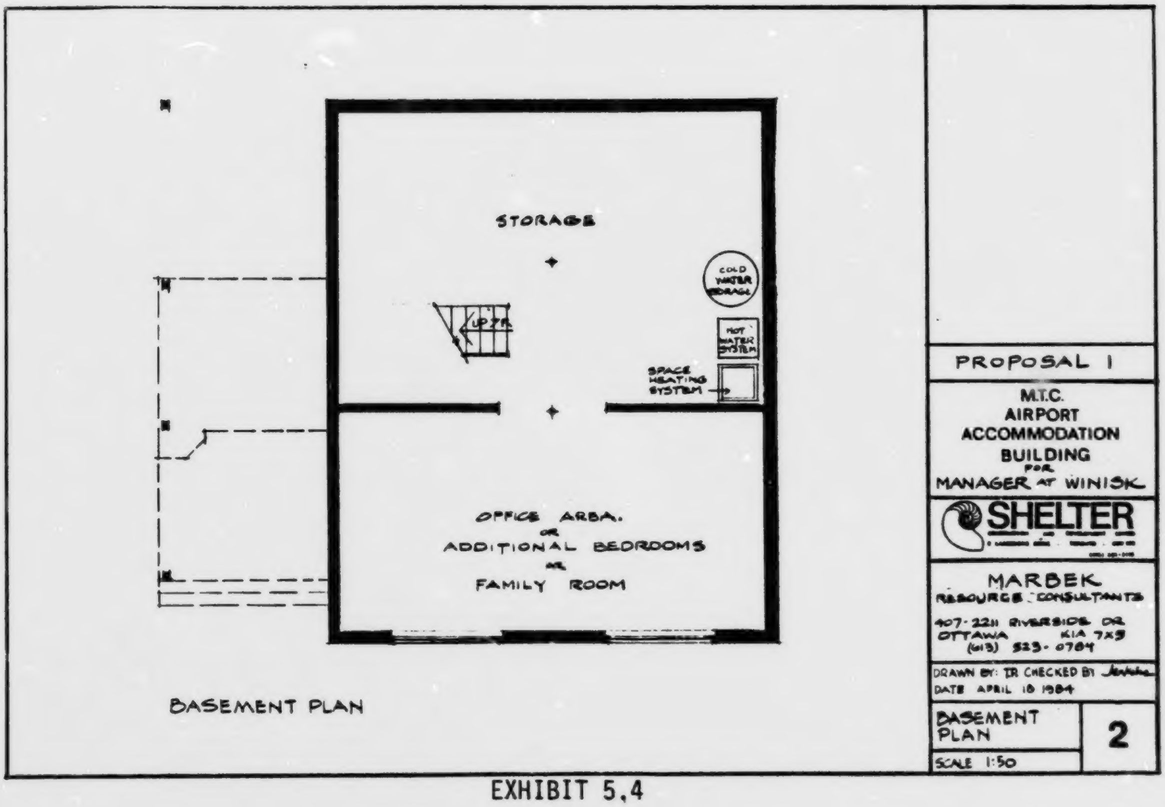

STORAGE
COLD WATER STORAGE
HOT WATER SYSTEM
SPACE HEATING SYSTEM
UP 7R
OFFICE AREA
OR
ADDITIONAL BEDROOMS
OR
FAMILY ROOM
BASEMENT PLAN
PROPOSAL 1
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
FOR
MANAGER AT WINISK
SHELTER
MARBEK
RESOURCE CONSULTANTS
407-2211 RIVERSIDE DR
OTTAWA K1A 7X5
(613) 523-0784
DRAWN BY: TR CHECKED BY
DATE APRIL 10 1984
BASEMENT PLAN
2
SCALE 1:50

EXHIBIT 5.4

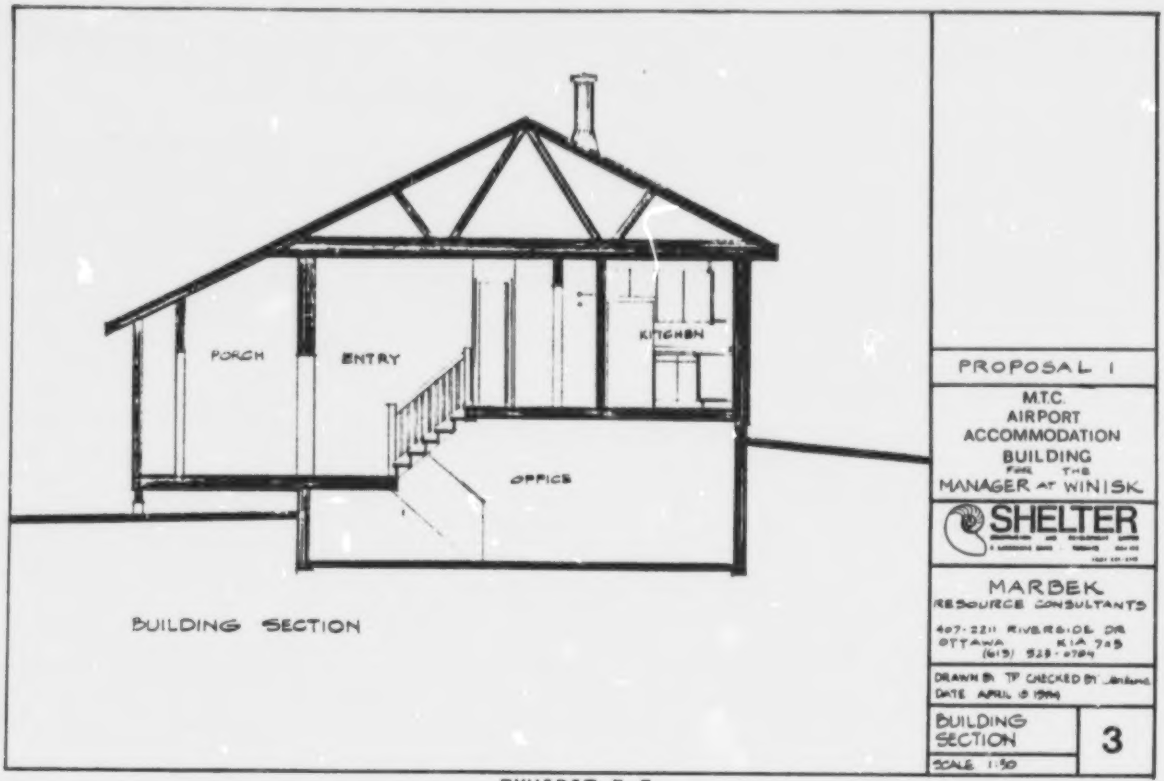

PORCH
ENTRY
KITCHEN
OFFICE
BUILDING SECTION
PROPOSAL 1
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
FOR THE
MANAGER AT WINISK
SHELTER
MARBEK
RESOURCE CONSULTANTS
407-2211 RIVERSIDE DR
OTTAWA KIA 7A5
(613) 523-0784
DRAWN BY TP CHECKED BY
DATE APRIL 18 1984
BUILDING SECTION
3
SCALE 1:50

EXHIBIT 5.5

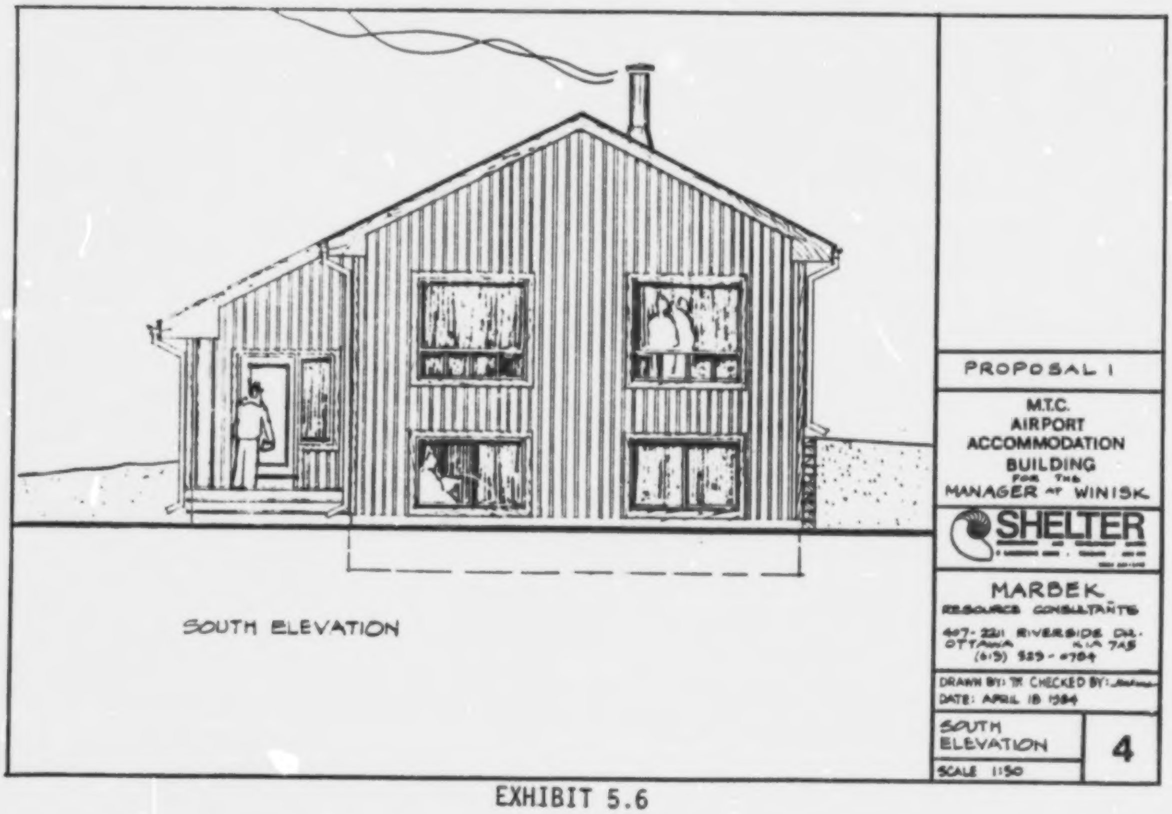

SOUTH ELEVATION
PROPOSAL 1
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
FOR THE
MANAGER AT WINISK
SHELTER
MARBEK
RESOURCE CONSULTANTS
407-2211 RIVERSIDE DR.
OTTAWA KIA 7A5
(613) 523-0784
DRAWN BY: TP CHECKED BY:
DATE: APRIL 18 1984
SOUTH ELEVATION
4
SCALE 1:50

EXHIBIT 5.6

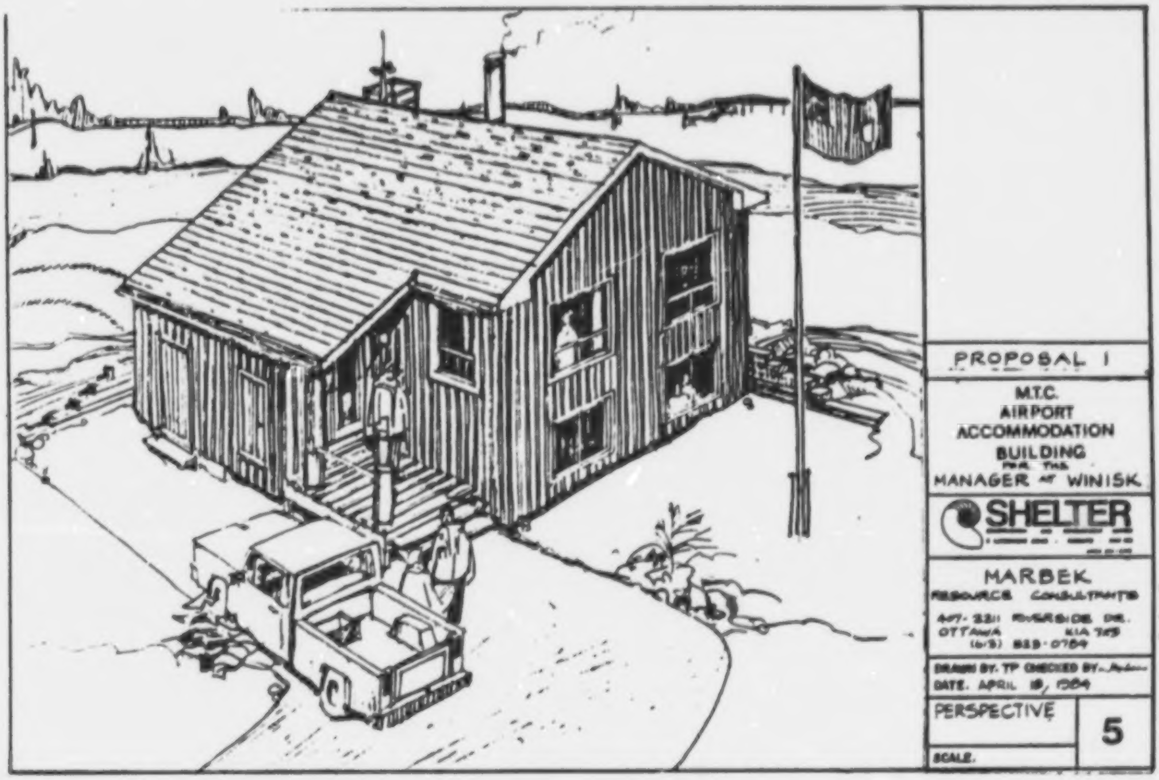

PROPOSAL 1
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
FOR THE
MANAGER AT WINISK
SHELTER
MARBEK
RESOURCE CONSULTANTS
447- 2211 RIVERSIDE DR.
OTTAWA K1A 7X5
(613) 523-0784
DRAWN BY. TP CHECKED BY.
DATE. APRIL 19, 1984
PERSPECTIVE
5
SCALE.

EXHIBIT 5.7

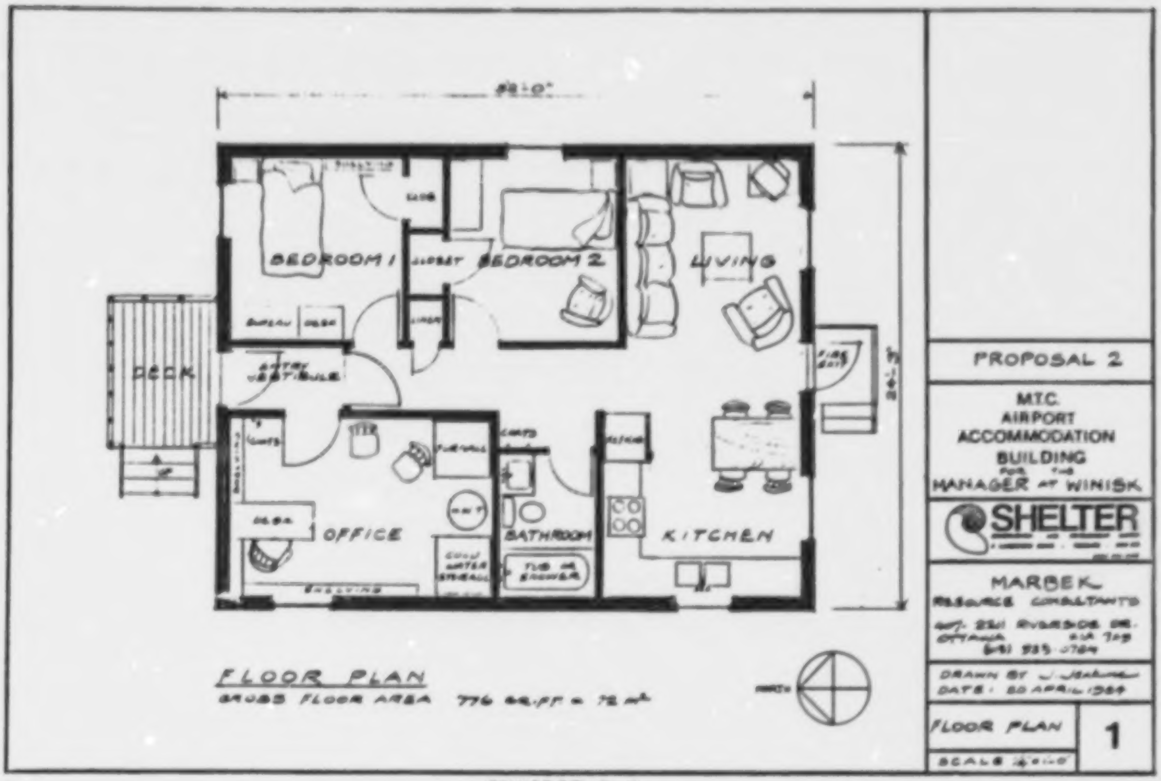

BEDROOM 1
CLOSET
BEDROOM 2
LIVING
DECK
ENTRY VESTIBULE
FIRE EXIT
OFFICE
BATHROOM
TUB OR SHOWER
KITCHEN
FLOOR PLAN
GROSS FLOOR AREA 776 SQ.FT = 72 m²
NORTH
PROPOSAL 2
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
FOR THE
MANAGER AT WINISK
SHELTER
MARBEK
RESOURCE CONSULTANTS
DRAWN BY
DATE: 20 APRIL 1984
FLOOR PLAN
SCALE
1

EXHIBIT 5.8

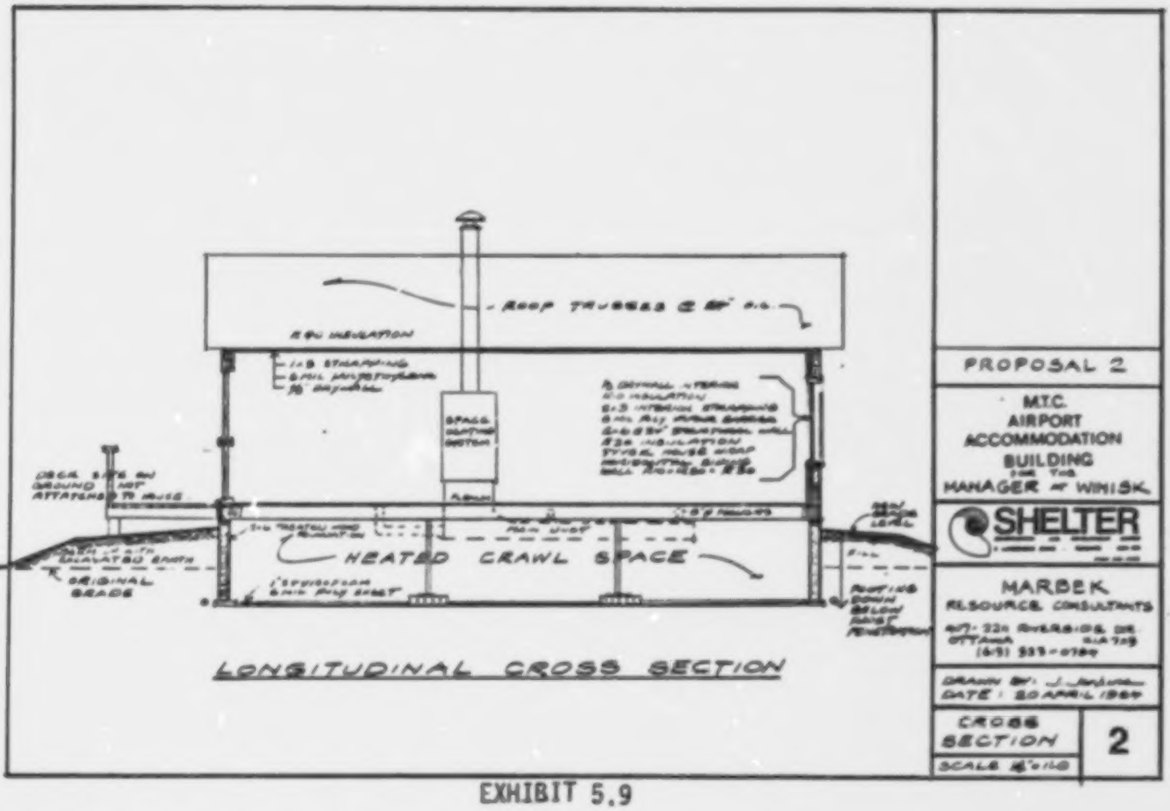

ROOF TRUSSES
SPACE HEATING SYSTEM
DECK SITS ON GROUND NOT ATTACHED TO HOUSE
ORIGINAL GRADE
HEATED CRAWL SPACE
FILL
LONGITUDINAL CROSS SECTION
PROPOSAL 2
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
FOR THE
MANAGER AT WINISK
SHELTER
MARBEK
RESOURCE CONSULTANTS
DRAWN BY
DATE: 20 APRIL 1984
CROSS SECTION
SCALE
2

EXHIBIT 5.9

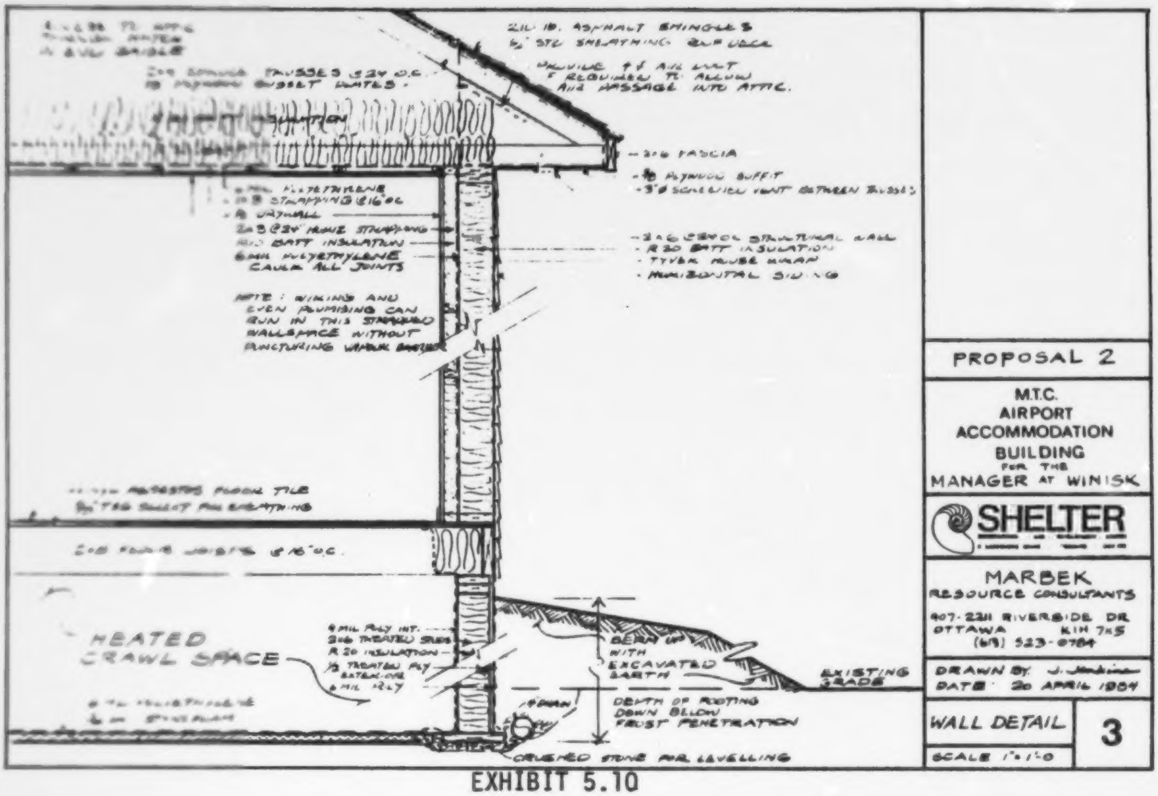

210 lb. ASPHALT SHINGLES
½" STD SHEATHING ROOF DECK
PROVIDE 4" AIR DUCT IF REQUIRED TO ALLOW AIR PASSAGE INTO ATTIC.
2x4 SPRUCE TRUSSES @ 24" O.C. ⅜ PLYWOOD GUSSET PLATES
2x6 FASCIA
⅜ PLYWOOD SOFFIT
3" Ø SCREENED VENT BETWEEN TRUSSES
6 MIL POLYETHYLENE
1x3 STRAPPING @ 16" OC
½ DRYWALL
2x3 @ 24" HORIZ STRAPPING
R12 BATT INSULATION
6 MIL POLYETHYLENE CAULK ALL JOINTS
NOTE: WIRING AND EVEN PLUMBING CAN RUN IN THIS STRAPPED WALLSPACE WITHOUT PUNCTURING VAPOUR BARRIER
2x6 @ 24" O.C. STRUCTURAL WALL
R 20 BATT INSULATION
TYVEK HOUSE WRAP
HORIZONTAL SIDING
ASBESTOS FLOOR TILE
⅝" T&G SHEET PLY SHEATHING
2x8 FLOOR JOISTS @ 16" O.C.
HEATED CRAWL SPACE
4 MIL POLY INT.
2x6 TREATED STUDS
R 20 INSULATION
½ TREATED PLY EXTERIOR
6 MIL POLY
BERM UP WITH EXCAVATED EARTH
EXISTING GRADE
DRAIN
DEPTH OF FOOTING DOWN BELOW FROST PENETRATION
CRUSHED STONE FOR LEVELLING
PROPOSAL 2
M.T.C. AIRPORT ACCOMMODATION BUILDING FOR THE MANAGER AT WINISK
SHELTER
MARBEK RESOURCE CONSULTANTS
407-2211 RIVERSIDE DR. OTTAWA K1H 7X5 (613) 523-0764
DRAWN BY: J. Jenkins
DATE: 20 APRIL 1984
WALL DETAIL
3
SCALE 1"=1'-0"

EXHIBIT 5.10

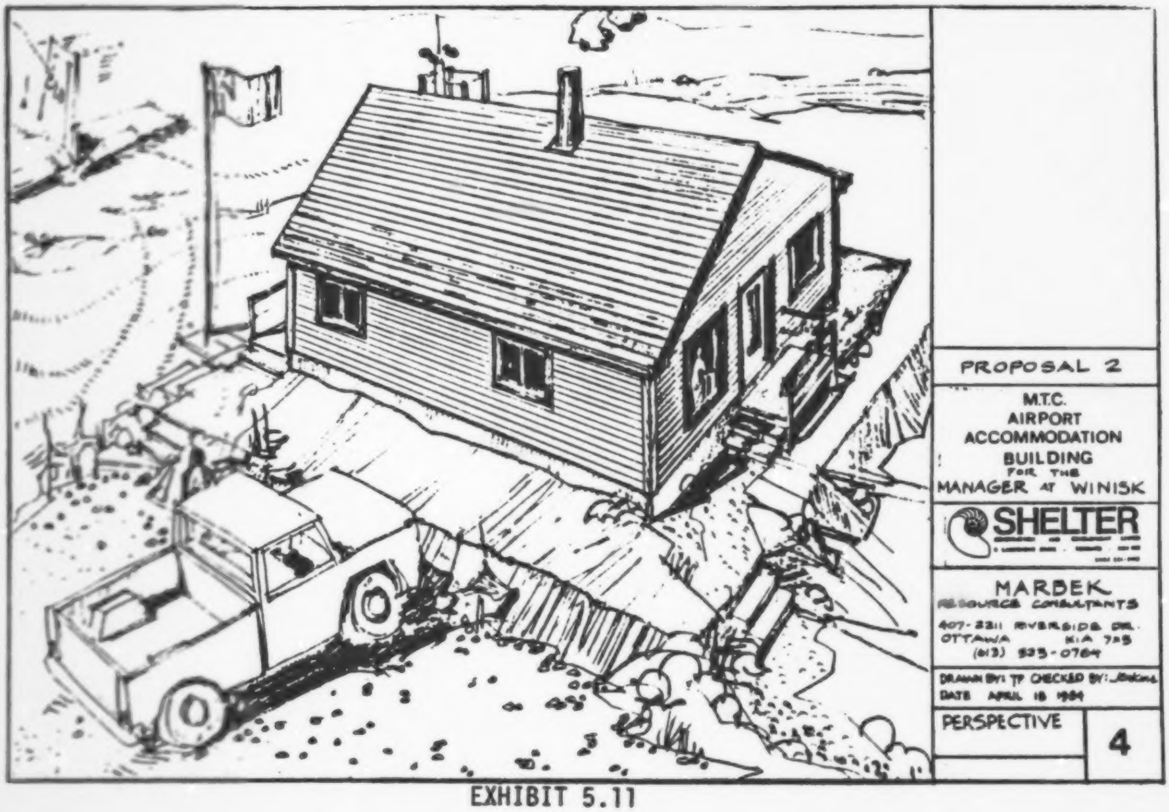

PROPOSAL 2
M.T.C. AIRPORT ACCOMMODATION BUILDING FOR THE MANAGER AT WINISK
SHELTER
MARBEK RESOURCE CONSULTANTS
407-2211 RIVERSIDE DR. OTTAWA K1A 7X5 (613) 523-0764
DRAWN BY: TP CHECKED BY: J. JENKINS
DATE APRIL 18 1984
PERSPECTIVE
4

EXHIBIT 5.11

Either design could be built with fully condensing oil or propane space/water heating and an air to air heat exchanger unit. Both designs involve some building techniques or equipment that require the contractor to have some experience in energy efficient construction.

5.3.4 Estimated Costs and Savings

Both designs should have an annual fuel consumption of less than 1,500 l/year (the heat loss calculations in Section 4 show that a similar sized house built to lower energy efficiency standards has an estimated annual fuel consumption of 1,640 litres/year). The cost of heating the house would therefore be approximately $1,500 per year or less if a condensing oil furnace were used, for annual savings of at least $3,000/year.

Assuming that the house must be replaced anyway, these savings must be compared with the additional cost of building to energy efficient standards. In Section 4 the additional cost for a house of this type (including a fully condensing furnace) was estimated to be about $6500. The simple pay back period is therefore about 2 years.

5.3.5 Recommended Action

It is recommended that the current airport manager's house be replaced by a new one built according to one of the proposed designs presented in Section 5.3.3. The house should encorporate fully condensing oil furnace/water heater and an air/air heat exchanger. The house should be built by a contractor with some experience in energy efficient housing construction.

5.4 WINISK AIRPORT WAITING ROOM

5.4.1 Description

This 6m X 6m single storey wood frame building houses a waiting area and Austin Airways' agent office. It has 2" X 4" walls with an additional 2" interior strapping. It is estimated that the walls contain about 15 cm. of insulation. The floor is uninsulated boards over an unheated crawl space. The ceiling cavity is unaccessible but may be assumed to contain about 10 cm. of old insulation. The finish is plywood throughout. There are two doors, one which has an entry alcove which acts as an air lock. There are two double vertical sliding wood frame windows. Heat is provided by a new 47,000 Btu/hr. Coleman Stove which is in good condition.

The building is moderately leaky due to a broken window and poor fitting doors but the stove appears to be capable of maintaining temperatures of 10 to 18^{0}C at design exterior temperatures (-38^{0}C).

Electrical consumption in the waiting room may be assumed to be negligible.

5.4.2 Current Fuel Consumption and Costs

A summary space heating balance for the Winisk airport waiting room is given in Table 5.5. The detailed calculations appear in Appendix J. Design interior and exterior temperatures and degree day values below 18°C used in the calculations were the same as those used in the hotel and house energy balances.

TABLE 5.6

WINISK AIRPORT WAITING ROOM
SPACE HEATING ENERGY BALANCE

Design temperatures: -38°C (-36°F) exterior
18°C (65°F) interior

Degree Days: 8600 below 18°C

Building Component	RSI Value	Area m^2	T °C.	Design Heat Loss Watts	Annual Heat Losses kWh/year
Walls	3.8	53	56	780	2,900
Ceiling	3.8	36	56	530	2,000
Floor	0.4	36	56	5040	18,600
Windows	0.7	3	56	230	900
Doors	0.7	4	56	330	1,200
				6910	25,600
Infiltration (1 air change per hour)				1690	6,200
	TOTAL:			8600	31,800

Annual fuel load (50% burner efficiency)
= 6000 litres/year

As shown in Table 5.6, the annual space heating load is approximately 32,000 kWh. Assuming a 50% average oil stove efficiency and a heating value for fuel oil of 10.6 kWh/litre, the estimated annual fuel consumption is 6,000 litres. At the current on-site fuel cost of $1.05/litre, this is equivalent to $6,300/yr.

5.4.3 Retrofit Measures

Transmission losses through the floor and infiltration losses are the largest sources of heat loss in the waiting room. Infiltration losses could be reduced by improving weatherstripping on the two doors (and by replacing broken windows). Floor losses could be reduced by laying a new floor on 2 x 3 strapping with fibreglass insulation between the two floors. This would increase the floor insulation value to about RSI 1.8 and reduce floor losses from 18,600 kWh/yr to 4,100 kWh/yr. At 50% burner efficiency, this would be equivalent to a fuel reduction of 2,700 l/yr or $2,900/yr. The cost of the new floor would be approximately as follows:

Insulation 36m^2 @ $2/m^2	$ 75
Lumber	$1,000
Labour 30hrs @ $15/hr	$ 450
Freight	$ 200
	$1,725

The simple pay back on the new floor is therefore less than 1 year. The savings, however, will only be achieved if the oil stove setting can be reduced to a low level, otherwise, reducing heat losses will only increase the room temperature.

5.4.4 Recommended Action

It is recommended that a new insulated floor be laid in the Winisk airport waiting room, that the oil stove be reduced to its lowest setting, and that new weatherstripping be installed on the two exterior doors.

5.5 WINISK POWER SYSTEM

5.5.1 Description

Electrical power is currently provided at Winisk MTC Airport by three 75 kW diesel generator sets (downsized to 50kW) operated by Ontario Northland Transportation Commission. Only one unit is operated at a time, the other two units being maintained as back-up units. There is no automatic switching between units. In the event of a unit failure or routine maintenance, switching is carried out manually by the resident airport manager. There are three electrical power users at Winisk airport - MTC (airport buildings, runway lights, etc.), DOT (navigation beacon), and Telsat Canada (satellite communications site).

The generator room is spacious and well maintained. Each generator set has a system for heat recovery from the liquid cooled engines. Air is blown through the radiators by engine fans into a ducting system which heats the adjacent garage and work area. Exhibits 5.12 and 5.13 show the Winisk generator sets and generator switchboard, respectively. Exhibit 5.14 is a view of the Winisk satellite station. System details are:

Generators: 75 kW, 97.5 KVA, 0.8 Power Factor, 120/-208 volt, three phase, four wire, 60 cycle, 40^{o}C temperature rise. Made by Stanford.

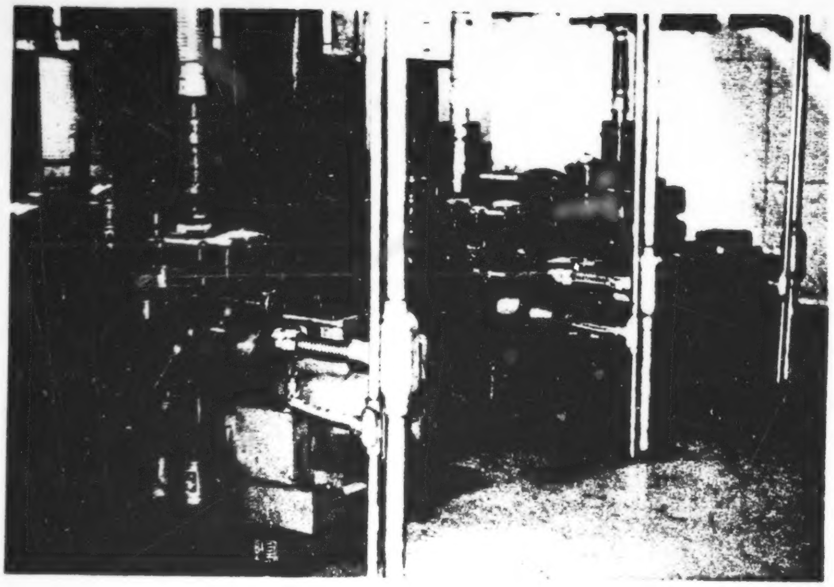


Exhibit 5.12: WINISK DIESEL GENERATOR SETS

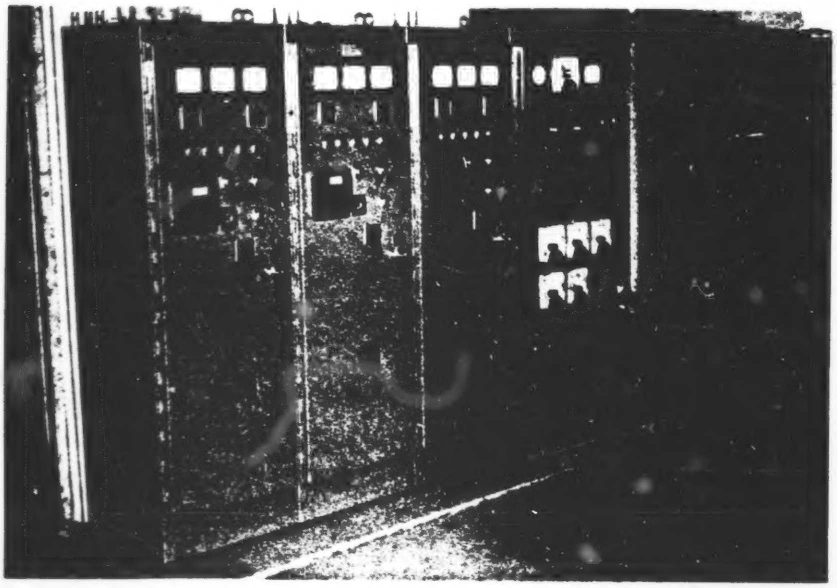


Exhibit 5.13: WINISK DIESEL GENERATOR SWITCHBOARD

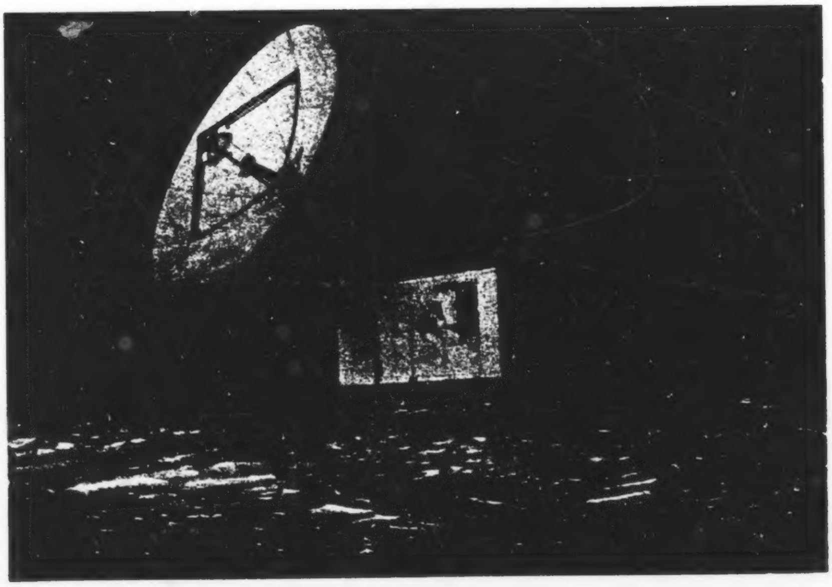


Exhibit 5.14: WINISK SATELLITE STATION

Engines:	3 X Detroit Diesel, model 4-71N, displacement 284 cu.in. RPM 1800, 2 Stroke cycle, naturally aspirated (positive displacement scavenger blower). Maximum H.P. is 115 @ 1800 RPM; Fan H.P. is 6; H.P. required for generators is 108. Engines are liquid cooled (glycol/water). Cooling air from the radiator can be diverted to heat the garage, workshop or both. Dampers are manually operated. Combustion air and cooling air are drawn into the engine room from the garage.

5.5.2 Current Fuel Consumption

During the site visit, the load did not exceed 20kW between approximately 1pm and 9pm.

With a 20 kW load it was estimated that one generator set would burn 9.0 litres/hour of fuel and produce 89,000 Btu/hr of recoverable waste heat. This heat would maintain the garage and workshop at an average 1°C at the design exterior temperature of -38°C. During the site visit, the damper on the ducting system was balanced in favour of the workshop. The observed garage temperature was about -5°C and the workshop about 10°C. Detailed power system and heat recovery calculations are given in Appendix J.

An estimated breakdown of the maximum loads that would be placed on the power generator is shown in Table 5.7.

It is estimated that the maximum load on the generators would be about 35kW. The (1983) average annual load was 26.5kW as contained in power consumption data provided by ONTC and shown in Table 5.8. At a 26.5kW year-round average, the fuel consumption would be about 90,000 litres/yr which agrees well with the average $100,000 per year spent by ONTC on fuel for the generator sets. It also agrees well with the airport manager's estimate that 300 US gallons of fuel oil are added to the inside fuel tanks every 5 days. A single 25,000 gallon bulk fuel oil storage tank is topped up each year to meet the generator set's fuel requirements.

The electrical load at Winisk may therefore be summarized as follows:

Maximum load: 35 kW
Minimum load: 15 kW
Average load: 26.5 kW

Annual electrical output: 232,000 kWh/yr
Annual fuel consumption: 90,000 l/yr.

TABLE 5.7

WINISK AIRPORT AND TELECOMMUNICATIONS - Electrical Load Breakdown

End Use	Maximum Load (kW)	
Telsat Communications		
Heater/Chiller	4.5kW	
Batteries/Comm. Equip.	2.5kW	
Miscellaneous	.5kW	
	7.5kW	7.5kW
Beacon and Runway Lights		20 kW
Hotel, Garage and House lights, appliances, motors, tools, etc.		8 kW
TOTAL:		35.5kW

TABLE 5.8
POWER CONSUMPTION* (kWh) AT WINISK AIRPORT IN 1983

MONTH	MTC	MOT	TELESAT	TOTAL
March	12,800	2,760	2,860	18,420
April	19,040	1,660	5,780	26,480
May	16,036	4,700	2,460	23,196
June	8,080	3,060	1,100	12,240
July	7,900	3,020	1,840	12,760
August	10,540	3,220	5,820	19,580
September	11,272	5,220	3,700	20,192
October	13,648	1,080	3,580	18,308
November	19,436	3,220	3,380	26,036
December	11,580	2,440	2,420	16,440
Average Consumption (kWh/mo)	13,033	3,038	3,294	19,365
Average Power (kW)	17.8	4.2	4.5	26.5

*Measured data; data not available for January and February.

Source: Ontario Northland Transportation Commission

5.5.3 Retrofit Wind Turbine Generator

The most promising means to reduce fuel consumption for power generation at Winisk is to install a wind turbine generator. The wind regime at Winisk is good, with strong winds off Hudson Bay and a flat terrain. The average wind probability distribution for Winisk is given in Figure 5.1. The mean wind speed is 5.8 m/sec.

Design considerations: The diesel generators at Winisk are in good operating condition. If a wind turbine generator is to be considered to reduce fuel consumption, the only option is to install a wind generator adjacent to the hangar building and connect the output electrically to the present power system. A mechanical connection between the wind turbine and diesel units is not possible because of the engine layout in the generator room and because the large hangar, which houses the generator room, would shelter the wind generator and reduce its output.

Two types of electrical connection are possible:

- a simple parallel connection in which a diesel generator continues to run at all times and the wind generator, in effect, becomes a negative load;
- a stand alone connection in which the diesel generators are shut down when the wind generators can meet the load.

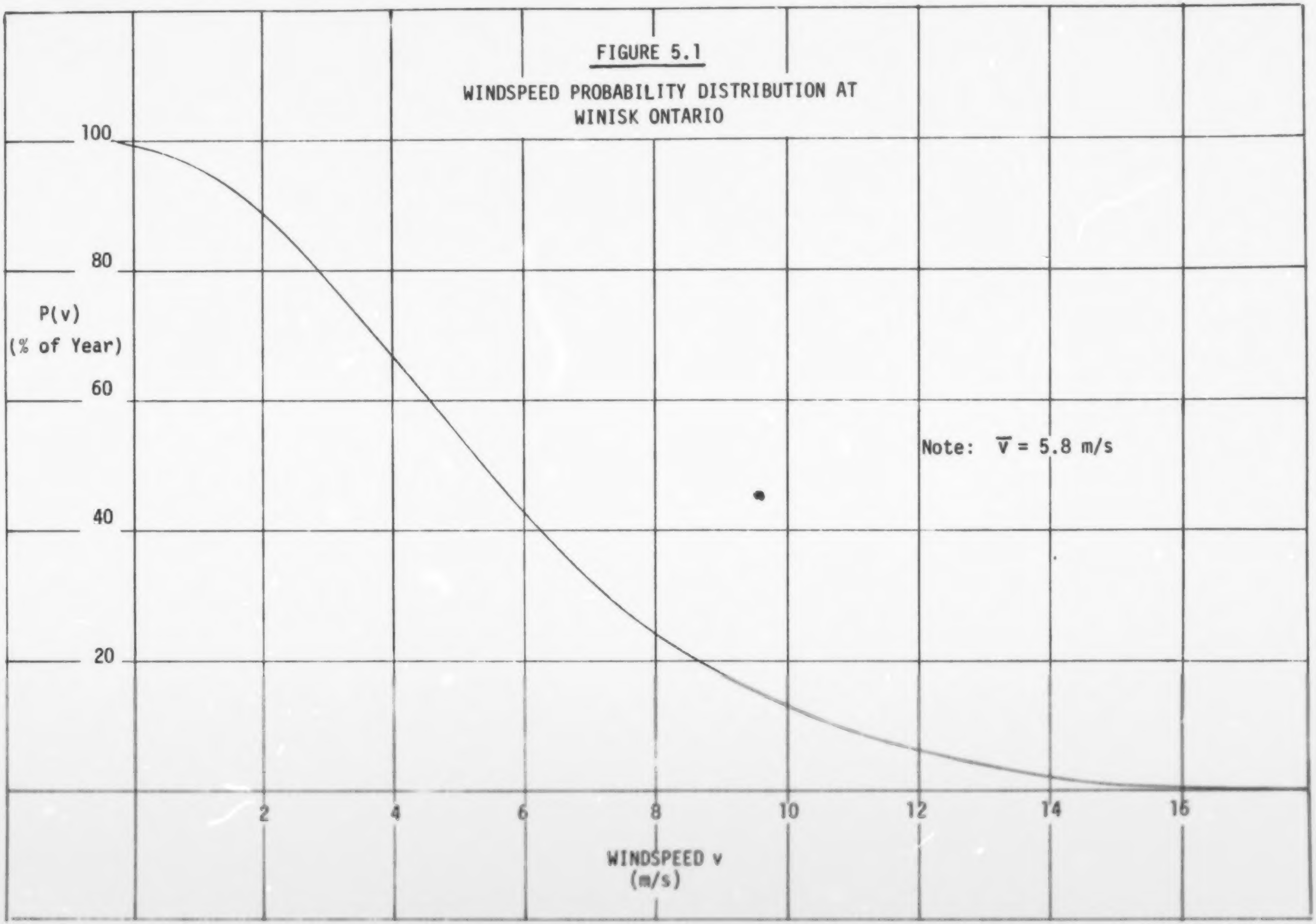


FIGURE 5.1

WINDSPEED PROBABILITY DISTRIBUTION AT
WINISK ONTARIO

Note: $\overline{v} = 5.8$ m/s

In considering the economics of adding a wind turbine at Winisk, the cost of purchasing, shipping, installing and maintaining the unit must be set against the value of energy saved. In the stand-alone mode, there will also be savings in maintenance because of the reduced running time of the diesel engines.

With a simple parallel connection, an induction generator could be used and connected to the continuously running diesel generator through an auto synchronizer. In a stand alone mode, a sychronous generator would have to be used. In either case a dummy load would be required to dump excess wind generated energy. If the wind turbine is not self starting and has a synchronous generator, then a separate starting motor with slip clutch would be required. If it has an induction generator, then the generator itself could be used to start the turbine.

System Design: Most wind turbine generators have a cut in speed of about 5 m/s and reach their rated output at about 15 m/sec. This means that at Winisk, wind generated electricity can be produced only when the wind is blowing at above average windspeeds.

If the wind generator is to generate in a stand-alone mode during this period, then it should be sized such that it can handle the average load on its own. It should therefore be able to meet the average load of 26.5 kW at a wind speed of about 8 m/sec (the median windspeed during operation). This means that a turbine rated at 60 to 80 kW would be needed.

If the diesel generators are to be kept running, then the wind generator should be sized such that it meets the average load of 26.5 kW at a wind speed of 15 m/sec (the maximum windspeed during operation) so that the diesel engine is idling (no load) for a minimum amount of time. A turbine rated at 15 to 30 kW would therefore be most suitable for this option.

The two wind turbine options for Winisk are therefore as follows:

- 60 to 80 KW turbine with synchronous generator and dump load for stand-alone operation. (If not self starting, a slip clutch and electric starter motor powered by diesel generator is required)
- 15 to 30 kW turbine with induction generator, dump load, and autosynchronizer for connection to continuously running diesel generator. (If not self starting, starting is carried out by energizing the induction generator)

Turbine Selection For Stand Alone Option: Wind turbines with synchronous generators or special synchronizing equipment for stand alone or grid connection have only recently become commercially available. Most of these are in the 100-500kW range. There is, however, some work being carried out on the development of smaller machines, and units in the 15-100kW range should be available within a year. Ontario Hydro, NRC, and OME are currently testing a 50kW DAF vertical axis machine with an induction generator and special synchronizing equipment at Coniston, Ontario. Northwind Power, one of North America's leading companies in remote wind turbine systems is working with Mechron Energy Ltd. of Ottawa, and Hawker Sidley of Britain on the development of stand alone synchronized wind/diesel hybrid based on their 16kW L-916 model. James Howden & Co. are about to introduce a 60kW version of their successful HWP-200 synchronous machine at a cost of $75,000.

Turbine Selection for Continuous Running Diesel Option: Suitable wind turbines for simple electrical connection to a continuously running diesel generator are few. Wind turbines rated at 15 to 100 kW with induction generators for grid or continuous prime power system use have been developed primarily for wind farm application. There is very little information available on the operation of these units in adverse weather conditions. The Canadian DAF Indal 50 KW vertical axis generator, though oversized for the continuous running option, has operated reliably in Canadian arctic conditions. The VESTAS 65 kW horizontal axis generators, also oversized for this application, have operated reliably in the very gusty and stormy conditions experienced in northern Europe. The advantages of the Vestas machine is that it has dual generators which allow it to operate at low windspeeds at higher efficiency. Northwind Power make a 16 kW induction machine for remote use but do not yet have much Canadian experience with them.

5.5.4 Estimation of Potential Wind Energy Contribution

The amount of electrical energy that can be produced by a wind turbine in a given wind regime is given by the equation derived in Appendix K:

$$\text{Energy Produced} = 0.61\ C_p\ (A_t)(A_w)(V_m)^2\ T$$
(watt hrs/yr)

where C_p = coefficient of performance of the wind turbine, including rotor efficiency, gearbox losses, etc.

A_t = cross sectional area of rotor (m^2)

A_w = area under the wind probability curve between rotor cut-in speed and rotor cut-out speed (m/sec)

V_m = mean wind speed during rotor operation (m/sec)

T = rotor run time (hrs/yr)

The maximum and minimum loads at Winisk were estimated to be 35 kW and 15 kW respectively. A wind turbine that has a power output greater than 15 kW at Winisk windspeeds (0-15 m/sec) will therefore produce excess power for some period of the year. A worst case estimate may be obtained by assuming that the wind turbine contributes energy only when the wind speed is between the cut in speed and the speed which produces 15 kW. A best case estimate would assume energy is contributed up to the speed which produces 35 kW.

Table 5.9 gives estimates of annual energy contributions (best and worst cases) for two wind turbines - the DAF INDAL 50 KW VAWT and the Northwind L-916 HAWT. Coefficients of performance and rotor areas were taken from manufacturer's specifications. Annual performance was calculated using the equation derived in Appendix K and the Winisk wind data given in Figure 5.1.

TABLE 5.9

ESTIMATES OF ANNUAL WIND ENERGY CONTRIBUTIONS

AT WINISK

Wind Turbine	**DAF Indal VAWT**	**Northwind L-916**
Rated size	50. KW	16. KW
Cut-in-seed (m/s)	5.0	4.5
15 KW Speed (m/s)	8.2	12.8
35 KW Speed (m/s)	12.5	-
Coeficient of Performance (C_p)	0.34	0.33
Rotor area (m^2)	98.	64.
Operating time:		
Worst Case (hrs/yr)	2,628	4,906
Best Case (hrs/yr)	4,294	5,256
Annual wind contribition:		
Worst case (KWh/yr)	27,000	66,000
Best case (KWh/yr)	75,000	79,000
Average (KWh/yr)	51,500	72,500

Table 5.9 shows the importance of a low starting speed and matching the wind turbine to the load. The 16 kW turbine with a low starting speed contributes a larger amount of energy over the course of a year than the oversized 50 KW turbine with a higher starting speed. The better load/contribution match of the 16 kW turbine is illustrated by the small difference between best and worst case estimates.

5.5.5 Estimated Costs and Savings:

Diesel Fuel Costs: Current annual fuel consumption and costs at Winisk for power production are, respectively, 90000 litres and $94,500. Total power production at Winisk has been shown to be 232,000 kWh/yr. Therefore average annual fuel costs for power production are about 41¢/kWh. The annual fuel savings from a wind generator will be equal to 41¢ x (wind generator contribution in kWh/yr.)

If the wind turbine and diesel generator sets are operated in a continuous-run mode, the fuel savings will not be as if the wind turbine were operated high as in a stand-alone mode. This is because the specific fuel consumption (kg/hr.kW) of the engines is higher at reduced loads. The current average specific fuel consumption of the Winisk diesel sets at the average electrical load of 26.5kW is 0.26 kg/hr.kW. From Table 5.9, addition of the DAF 50kW would reduce annual fuel consumption to 179,000 kWh/yr, reduce the average load on the continuously running diesel to 20.5kW, and increase the engine specific fuel consumption to 0.29 Kg/hr.kW. Addition of the Northwind L-916 would increase engine specific fuel consumption to 0.3 kg/hr.kW. The actual fuel consumption of the diesel sets after addition of the wind turbines would therefore be 74,000 l/yr for the DAF 50kW and 70,000 l/yr for the Northwind L-916. At current fuel prices, the annual fuel cost would be $77,700 with the DAF 50 and $73,500 with the Northwind L-916.

Diesel Maintenance Costs: Current costs of repair and maintenance for the 3 diesel generator sets at Winisk, from ONTC records, are approximately $25,000/year. If a stand-alone wind generator system was installed, it can be assumed that these maintenance costs would be reduced (approximately) in direct proportion to the reduction of engine running time. However, in the continuous-run installation, diesel maintenance costs would be largely unaffected.

Transportation Costs: Shipping costs for the transportation of wind turbine equipment to Winisk would be considerable, especially if the components were too large for air transport using conventional aircraft (Hawker Sidley 748) or had to be brought in by winter road. Shipping costs in excess of $15,000 have been estimated for the large 50 kW DAF Indal turbine (Ontario Hydro, 1983). Normal charter or scheduled carriers with shipping charges between $1 and $2 per Kg could be used for small turbines like the Northwind L-916.

Installation Costs: Installation costs could be very high, especially if a crane or helicopter is required to erect the tower or install the generator on the tower. Installation costs for a 50 kW DAF turbine are estimated to be $60,000 including site preparation and equipment rental (Ontario Hydro 1983). Installation procedures are expected to be much less complex for the Northwind L-916 and are therefore estimated to be about $10,000 (based on company specifications)

Annual Turbine O & M Costs: Yearly O&M costs for the DAF 50kW turbine in a northern climate are estimated to be about $2,500 for parts and about $4,000 for labour (Ontario Hydro, 1983). No information is available on the O&M costs for the Northwind L-916. The company is cautious about recommending the unit for northern use until results are available from a scheduled a test at Hall Beach, NWT during the winter 1984/85. For a rough economic anaylsis, maintenance costs similar to those for the DAF machine may be conservatively assumed for the Northwind.

Turbine Costs: The factory cost of a DAF 50kW UAWT is quoted as $160,000 and the cost of a Northwind L-916 is quoted as $40,000, including tower.

Summary :Table 5.10 gives the estimated costs and savings for a DAF Indal 50 KW vertical axis turbine, and a Northwind L-916 in the continuous running diesel mode. It is not possible to conduct a proper economic analysis of the stand-alone mode because suitable turbines are not yet commercially available. Both equipment costs and fuel savings would be higher in the stand-alone mode. The introduction of a $75,000, 60kW Hawden synchronous generator unit would make the stand-alone mode more practical and cost effective.

TABLE 5.10

COSTS & SAVINGS FOR WIND/DIESEL HYBRID

SYSTEM AT WINISK

Wind Turbine	**DAF 50 KW**		**Northwind L-916**	
Capital Cost:				
Turbine	$160,000		$40,000	
Autosynchronizer	5,000		5,000	
Dummy Load	3,000		3,000	
Installation	$ 60,000		$10,000	
Shipping	$ 15,000		$ 5,000	
Total Capital Costs*	$243,000		$63,000	
Annual Cost of Capital @ 7% discount over 20 years	$ 22,900		$ 5,900	
Annual Maintenance Costs	$ 6,500		$ 6,500	
Total Annual Costs		$29,400		$12,400
Annual Fuel Savings @ $1.05/1 (allowing for higher specific diesel fuel consumption)		$16,800		$21,000
Net Annual Savings (Costs)		($12,600)		$ 8,600

* Note: Project Management costs have not been calculated or included.

5.5.6 Recommended Action

While the DAF 50 KW vertical axis turbine would be the most reliable unit to install at Winisk, it is oversized for the load in a continuous-run mode, and its price makes the proposition uneconomic. DAF do not have the 50 kW unit in commercial production, concentrating their efforts on the larger 500 kW unit. Even in quantities of 5 or 6 units, the 50 kW would cost $100,000 to $150,000 per unit.

The smaller 16 kW Northwind L-916 appears to be better matched to the load at Winisk for the continuous running diesel mode and offers greater potential savings than the DAF 50Kw turbine. This is a result of its lower capital and installation costs, its lower cut-in wind speed and the better matching of its rated 16Kw output with Winisk's power demand. Consequently, it is recommended that MOE/MTC monitor the performance of the Northwind L-916 at Hall Beach N.W.T. as well as continue MOE's current demonstration and development work with smaller Ontario wind turbines in the range of 15-30 KW. It is expected that within the next 2-3 years, the Northwind L-916 and other smaller Ontario wind turbines will have proven levels of technical reliability in severe remote conditions. At that time the desirability of installing such a system at Winisk should be re-assessed.

The development of larger synchronous wind machines, such as the 60kW Hawden, should also be monitored and the stand-alone option should be re-assessed when specific capital, installation and O&M costs are available.

PART C

MTC REMOTE COMMUNICATIONS FACILITIES

INTRODUCTION

Part C presents a comprehensive assessment of fuel and maintenance cost saving opportunities in MTC remote communications facilities in Northern Ontario. Discussion of the opportunities is presented in two sections:

Section 6: Intermittent charge Diesel Generator Sets for MTC Remote Communications Faciities

Section 7: Use of Photovoltaics to Reduce Fuel Consumption in Intermitten Charge Diesel Generating Systems for MTC Remote Communications Facilities.

SECTION 6

INTERMITTENT CHARGE* DIESEL GENERATOR SETS FOR REMOTE MTC COMMUNICATIONS SITES

6.1 INTRODUCTION

MTC is responsible for the cost of providing power at 14 communications sites in Northern Ontario. The power systems at these sites are operated and maintained for MTC by Bell Canada. The communications equipment at these sites is operated either by Bell Canada if a microwave system is used or by Telsat Canada if a satellite system is used. Telephone equipment (exchange or toll) is operated at all sites by Bell Canada. Three of the 14 sites (Bearskin Lake, Kasabonika, and Sachigo Lake) will be connected to community power in 1984 and are therefore not considered further. A summary of the communications equipment and agency responsibility at the other 11 sites is given in Table 6.1.

As shown in Table 6.1, the maximum continuous DC load required to run the satellite receiver, microwave tower and telephone equipment at the MTC remote communications sites varies only between 80 and 1400 watts. However, as shown in the following discussion, current practices require the use of 7.5kW to 20 kW diesel generating sets.

---

*Also known as Cycle Charge Prime Power Systems, a registered trademark of Mechron Energy Limited.

TABLE 6.1

MTC COMMUNICATIONS SITES IN NORTERN ONTARIO WITH CONTINUING POWER REQUIREMENTS

Community	Communications Equipment/Bldgs	Communications Equipment Load (Watts)	Responsible Agency		
			Capital	Operation	Fuel
Angling Lake	SRS repeater exchange equipment, DC power supply	80	Bell (Dryden)	Bell (Dryden)	-
	Exchange Bldg, heating and ventilation equipment	-	Bell (Th Bay)	Bell (Th Bay)	-
	Power system	-	MTC	Bell* (Th Bay)	Bell* (Th Bay)
Cat Lake Muskrat Dam Slate Falls Ogoki:	Satellite receiver, DC power supply	400	Telsat	Telsat	-
	Satellite bldg, heating and air conditioning equipment	-	Telsat	Telsat	
	Single toll telephone	negligible	Bell (Dryden)	Bell (Dryden)	-
	Power System	-	MTC	Bell* (Th Bay)	Bell* (Th Bay)
Deer Lake Kingfisher	Exchange equipment, DC power supply, microwave tower	800	Bell (Dryden)	Bell (Dryden)	
	Exchange bldg., heating and ventilation equipment	-	Bell (Th Bay)	Bell (Th Bay)	
	Power system	-	MTC	Bell* (Th Bay)	Bell* (Th Bay)

TABLE 6.1 Cont'd

Community	**Communications Equipment/Bldgs**	**Communications Equipment Load (Watts)**	**Responsible Agency**		
			Capital	**Operation**	**Fuel**
McDowell Lake North Spirit	Single toll telephone, DC power supply microwave, tower	450	Bell (Dryden)	Bell (Dryden)	
	Toll station bldg, heating and ventilation equipment	-	Bell (Th Bay)	Bell (Th Bay)	
	Power system	-	MTC	Bell* (Th Bay)	Bell* (Th Bay)
Poplar Hill	Exchange equipment, DC power supply, microwave tower (2 dish)	1400	Bel (Dryden)	Bell (Dryden)	
	Exchange bldg., heating and ventilation equipment		Bell (Th Bay)	Bell (Th Bay)	
	Power system		MTC	Bell* (Th Bay)	Bell* (Th Bay)

*Regional Bell Canada personnel out of Thunder Bay maintain, upgrade, and fuel all MTC power systems in the same way they operate Bell power systems at other sites. An annual billing from Bell Canada to MTC to cover those costs is made at the provincial level.

Because of the split agency responsibilities shown in Table 6.1, it is current practice for Telsat and Bell Canada communications groups to design and build a self contained satellite receiving station or microwave exchange/toll station which has its own DC power supply, heating system and ventilation system, and requires only a single connection to an external A.C. power supply. This means that the rectifiers in the DC power supply run continuously, and in the summer produce excess heat which must be removed by a large ventilation fan or air conditioning, depending on the temperature sensitivity of the communications equipment. The continuously running rectifiers in a 12V or 24V DC power system can draw up to 5kW AC, and extracting the excess heat adds an extra intermittent summer electrical AC load of up to 3 kW.

For simplicity, the self contained buildings are usually electrically heated in winter, which, depending on the size and energy efficiency of the building, can add an intermittent winter AC electrical load of up to 4.5 kW.

Adding intermittent loads of 600 watts for the waveguide dehydrator, 500 watts for tower lights, and 500 watts for lights and wall plugs, a self contained communications building can draw up to 11 kW AC as follows:

Rectifiers (DC power supply)	5.0
Heating or cooling	4.5
Dehydrator	0.6
Tower lights	0.5
Lights and wall plugs	0.5
	11.1 kW

Small satellite toll sites may draw less than this, and large exchange sites with overnight bunk house accommodation will draw more, but the maximum requirement will always be between 7 and 15 kW.

When AC power is supplied at a remote communications site by diesel generating sets which have their own electrical loads of about 2 kW for cooling fans, starter batteries etc, then sets in the 7.5 to 20 kW range are needed

6.2 CURRENT FUEL CONSUMPTION AND COSTS

Estimates of current fuel consumption and costs at existing MTc communications sites were obtained through an energy audit on the Slate Falls Telsat toll station power system, site checks of Bearskin Lake and Sachigo Lake exchange site power systems, and a review of Bell Canada fuel and maintenance costs for all MTC sites for the years 1981 through 1983.

6.2.1 Slate Falls

The Slate Falls power system consists of two Ball diesel sets, each rated at 7.5 kW.

The sets are housed in a small uninsulated metal cabin with very little clearance between the running engines and the walls. A common control panel is located between the power generators on the rear wall of the cabin. An environmental control system is supposed to maintain the inside temperature at a comfortable level for maintenance and good starting. During the site visit the inside temperature was no higher than outside (-30°C). The environmental control system was unable to provide any heating because the air supply for the engines is drawn from the cabin, which in turn pulls a continuous stream of cold air into the cabin. The temperature of the air leaving the cooling jacket, surrounding the cylinders, was 1.5°C (35°F). The exhaust temperature was 120°C (248°F).

The estimated continuous maximum load exerted on the generator by the single phone toll tation Telsat system is shown in Table 6.2

FIGURE 6.1
FUNCTIONAL BLOCK DIAGRAM
MECHRON ENERGY LTD.
CYCLE CHARGE
SERIES 2000
DIESEL GENERATOR SET

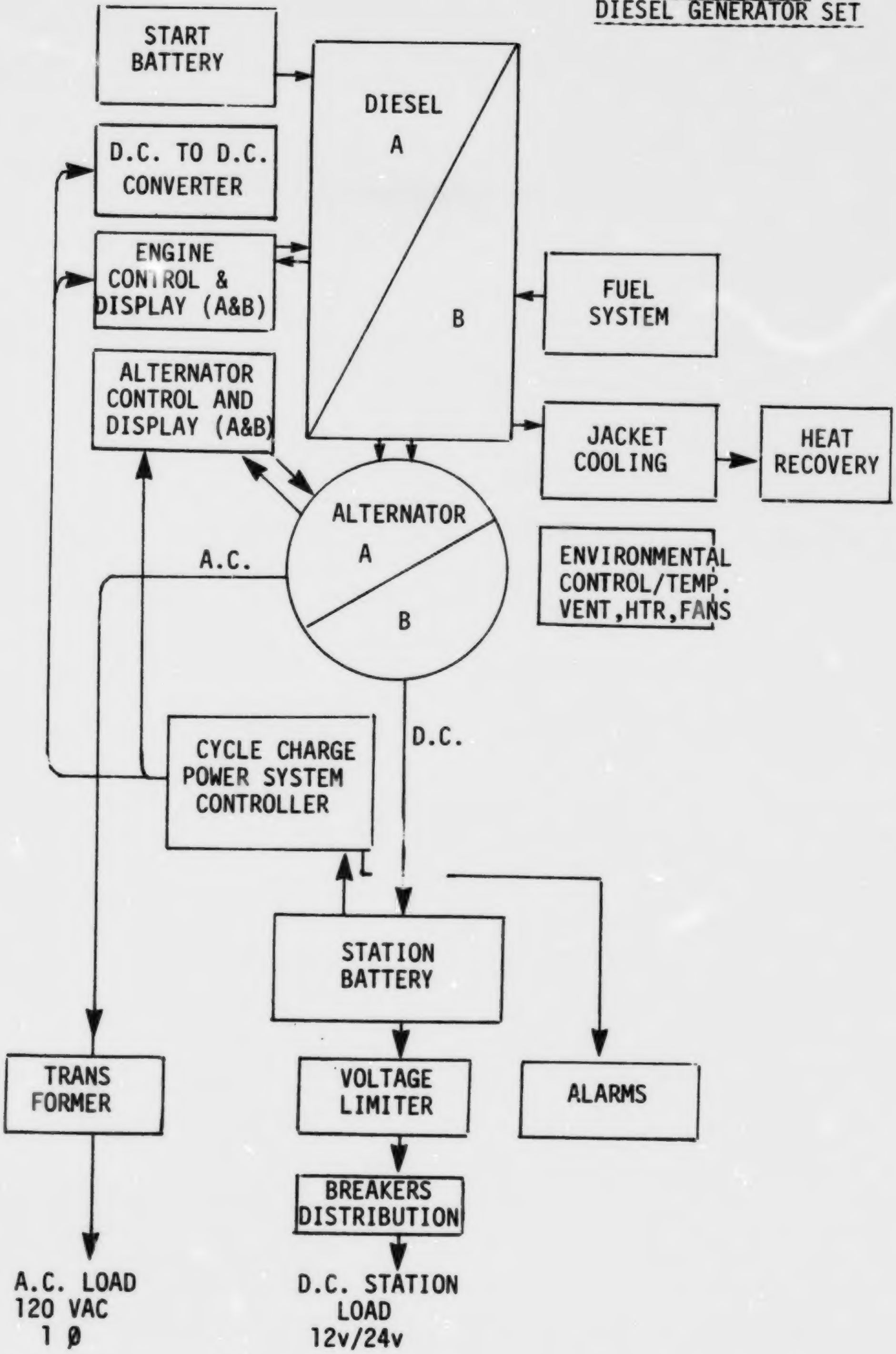

START BATTERY
DIESEL
A
B
D.C. TO D.C. CONVERTER
ENGINE CONTROL & DISPLAY (A&B)
ALTERNATOR CONTROL AND DISPLAY (A&B)
FUEL SYSTEM
JACKET COOLING
HEAT RECOVERY
ALTERNATOR
A
B
ENVIRONMENTAL CONTROL/TEMP. VENT,HTR,FANS
A.C.
D.C.
CYCLE CHARGE POWER SYSTEM CONTROLLER
STATION BATTERY
TRANS FORMER
VOLTAGE LIMITER
ALARMS
BREAKERS DISTRIBUTION
A.C. LOAD 120 VAC 1 Ø
D.C. STATION LOAD 12v/24v

TABLE 6.2

SLATE FALLS TELESAT SITE

- Electrical Load Breakdown

End Use	Load (kW)
Air conditioner (summer) or heater (winter):	4.5 kW
DC power system for battery charging and communications equipment:	2.5 kW
Miscellaneous lights, etc:	.5 kW
	7.5 kW

During the site visit the load was observed to be 4.1kW. At this load the annual fuel consumption is estimated to be 14,900 l/yr. Detailed power system calculatins are given in Appendix L.

6.2.2 Bearskin Lake

The diesel power system at Bearskin Lake consists of 2 Ball generator sets which use 10kW Lister ST-3 air cooled engines and Aircraft Appliancs and Equipment Company Model G1260-505 alternators rated at 15VA, 15 kW, 1.0 power factor, 125/62.5 amps, 120/240 Volts, 60 Hz. The load is a microwave exchange plus a small living cabin.

During the site check, the standby engine was being repaired. In order to maintain the generator cabin at a comfortable temperature, a plate on the outlet ventilation trunking had been removed, all inlet dampers had been closed, and the engine cooling air duct had been disconnected and closed. The propane fired space heater in the cabin is not used because of low clearances.

Measured power production was 15kW (65 amps & 60 amps on each leg). The high load was probably due to the extra power being drawn by the living cabin. An average load would be expected to be about 6 to 8kW, larger than Telsat sites because of the additional exchange, tower, and living cabin requirements. A 7 kW average load would be equivalent to an annual fuel consumption of about 20,000 litres/year.

The 10kW generator set was grossly overloaded during the site visit and is probably close to overload fairly frequently especially when exchange and living quarters heaters are on. The power system will, however, be redundant in 1984 when the facility is supplied with community power.

6.2.3 Sachigo Lake

The diesel power system at Sachigo consists of a 7.5 kW prime unit manufactured by Ball with a Lister ST-2 and Aircraft Appliances and Equipment alternator and a 20kW standby unit manufactured by Ball with a Lister HR-3 engine and unnamed alternator. The load is a Telsat satellite receiving station and exchange. The exchange is housed in a separate building which also includes temporary living quarters.

During the site check, the measured load was 4kW (14 and 19 amperes in each leg), only 50% of the prime engines' capacity. The generator cabin was even more cramped than at Slate Falls or Bearskin Lake because of the larger engines used. The standby unit uses an electric oil heater while the prime unit has the Ball system in which the oil is heated from a common sump. This means that if the standby unit fails while operating in cold weather, the prime unit could probably not be started.

A 4kW load could probably be considered low considering the communications equipment, exchange, two heater/chiller units, and lights used. A maximum load of about 14 kW would be experienced when the satellite exchange heating systems are both on and the two battery units are being charged at the full current limit. An 8kW average load would be equivalent to a fuel consumption of about 25,750 l/year.

6.2.4 Bell Canada Estimates of Fuel and Maintenance Costs

Table 6.3 gives Bell Canada delivered fuel quantities for MTC communications sites for the years 1981 through 1983. Fuel and maintenance costs for each site are given in Appendix Q. The average fuel cost for an MTC site from Bell Canada records is $11,400 per year and average total annual maintenance costs are $22,000 per year. Of this annual maintenance, $10,000 is estimated to be for routine maintenance (1 x $4500 overhaul on each engine every 18 months plus $4,000/yr agent fee).

TABLE 6.3

MTC REMOTE TELECOMMUNICATIONS SITES
DELIVERED FUEL QUANTITIES (1981, 1982, 1983)
AND 3-YEAR AVERAGE

Community	DELIVERED QUANTITY (litres) 1981	1982	1983	3-YEAR AVERAGE
1. Angling Lake	23,300	13,604	18,548	18,484
2. Bearskin Lake	16,123	21,089	14,398	17,203
3. Cat Lake	16,979	18,176	15,834	16,996
4. Deer Lake	19,863	11,497	15,918	15,759
5. Kasabonika	26,902	35,247	21,611	27,920
6. Kingfisher	16,929	23,913	14,340	18,394
7. MacDowel Lake	11,252	10,385	15,895	12,510
8. Muskrat Dam	22,761	17,135	11,961	17,286
9. North Spirit Lake	21,798	17,310	13,988	17,699
10. Ogoki	24,073	16,935	14,050	18,353
11. Poplar Hill	22,503	16,842	19,803	19,716
12. Sachigo Lake	28,835	20,773	11,395	20,334
13. Slate Falls	16,389	14,635	8,284	13,103
14. Wunnumin Lake	28,584	21,055	19,623	23,087
	296,291	258,596	215,648	256,844

6.3 INTERMITTENT CHARGE DIESEL OPTION: AN OVERVIEW

One alternative technical option is to use an intermittent charge diesel power system in which:

- the DC power supply is contained in the engine building rather than the communications building
- waste heat from the diesel engine is stored and used to provide space heating in the communications building
- all station electrical equipment is run on DC power

With only minor modifications to the existing exchange, toll or satellite/toll buildings, the intermittent charge system could replace the existing Ball or Mechron diesel sets at the MTC communications sites. Use of this system presents the following advantages:

- the size of the required power system is significantly reduced
- fuel consumption is reduced
- maintenance costs are reduced (reduced running time)

This type of system has the following effects on overall site power requirements:

- Intermittent operation changes the DC power system rectifier draw from a continuous 1-5kW to an intermittent 1-5kW.
- Removal of rectifiers and batteries from the communications building reduces the excess heat to be extracted to only that generated by communications equipment. This can be removed by a small ventilation fan. (In Northern Ontario there is no requirement for use of artificially cooled air for cooling since the maximum outdoor ambient temperature is below the maximum temperature requirements of the most sensitive communications equipment.)
- Use of waste heat recovery and heat storage reduces AC electrical heating requirements and changes this requirement from a large on-demand AC load to a small DC load which can be met when other electrical loads are at a minimum.
- Operating the dehydrator, cooling fan, back-up heaters, and tower lights on DC changes these loads from on-demand AC loads to a DC demand which is met by the intermittently charged battery system.

These factors reduce AC power requirements at a typical communications site to the following:

Rectifiers (DC power supply)	1-5kW
Miscellaneous (AC wall plugs, lights, etc.)	500 watts
	1-5.5 kW

Because of the intermittent charging, the diesel engines run at close to full load, they run only a fraction of the time, and heating and cooling fuel requirements are greatly reduced. Operation of an intermittent charge system of this type in Newfoundland showed that fuel consumption and engine running time were reduced by up to 70% (Newfoundland Telephone, 1982).

6.4 SYSTEM SPECIFICATIONS

This section presents specifications for an intermittent charge diesel generating system with waste heat recovery. The basic design concept involves housing the generating system and DC power supply in a new building attached to, but separated from the communications building. Hot water (glycol) storage tanks for building heating would be housed either inside the exchange building or in a plenum between the engine room and the toll or satellite/toll building. The two layouts are shown in Exhibit 6.1.

Specifications are provided with respect to each of the following aspects:

- system size
- power supply
- battery requirements
- building heating system
- building modifications
- control system

6.4.1 System Size

Using the proposed intermittent charge system concept, there are only three basic requirements for AC power:

- a rectifier to supply DC power, on an intermittent basis, to the station battery system which in turn supplies DC power, as required, to the communications equipment, dehydrator, heat circulation fans, cooling fan, tower lights, and back-up heaters

- wall plugs and lights in the engine and communications building (used only during maintenance)

- engine starter battery chargers and oil heaters

The generator set is sized such that it will run continuously to meet the maximum daily load experienced by the station battery system. At all other loads the engine will charge the batteries, on an intermittent basis, when the battery voltage drops below a set limit.

The maximum load on the batteries will be as follows:

Communications equipment:	80 to 1500 watts
Dehydrator:	500 watts
*Ventilation fan:	500 watts
Tower lights:	500 watts
*Back up electric heaters:	(Design heat loss - Waste heat contribution)

(* Heating and ventilation will not occur simultaneously.)

To determine the required size of the back-up electric heaters it is necessary to estimate the design back-up heat requirements of communications buildings and the amount of waste heat available from diesel engine operation. Appendix M gives heat loss calculations for a typical exchange building and a typical satellite/toll station building in Northern Ontario. These heat loss calculations show that the design heating load is about 55 watts/°C for an exchange building and 37.5 watts/°C for a satellite building. Assuming a minimum inside allowable temperature of 15°C and a design outside temperature of -38°C, the design heat losses are 2900 watts and 2000 watts respectively. In a typical liquid cooled, naturally aspirated diesel engine, the amount of waste heat recoverable from the engine jacket is approximately equal to 80% of the electrical load. The minimum waste heat recovery contribution will occur when the engine has to run only to provide the additional heating.

Electric heater capacity

= Design heat loss - Minimum waste heat contribution

= 2900 watts - 0.8 (Electric heater capacity)

Therefore required Electric heater capacity

= 1600 watts

The maximum DC load will therefore be as follows:

Communications Equipment	1500 watts
Dehydrator	500
Tower Lights	500
Back-up Heaters or Ventilation Fans	1600
Total:	4100 watts

A 5kW system will therefore be adequate to meet the load of either an exchange site or a satellite/toll site.

6.4.2 Power Supply

Figure 6.1 is a functional block diagram for a Mechron Energy Limited 5kW Cycle Charge Series 2000 diesel generating set that would be suitable for providing power at a remote MTC communications site. These intermittent charge units feature an alternator with a built in rectifier that can supply 12, 24, 36 or 48 volts DC in addition to 24 volt AC. The intermittently charged station battery system may be installed in the engine building along with a 24 volt/120 volt AC transformer and the unit control system. The liquid cooled engine features a jacket heat recovery system in which jacket coolant may be pumped to a remote glycol heat storage tank for use as a source of heat or to a conventional radiator. The Series 2000 unit therefore produces:

- DC power (up to 4.5)
- hot coolant for heating, and
- AC power (limited to 1kW when the station batteries are being charged)

Further detail, including a recommended engine, is provided in Appendix N.

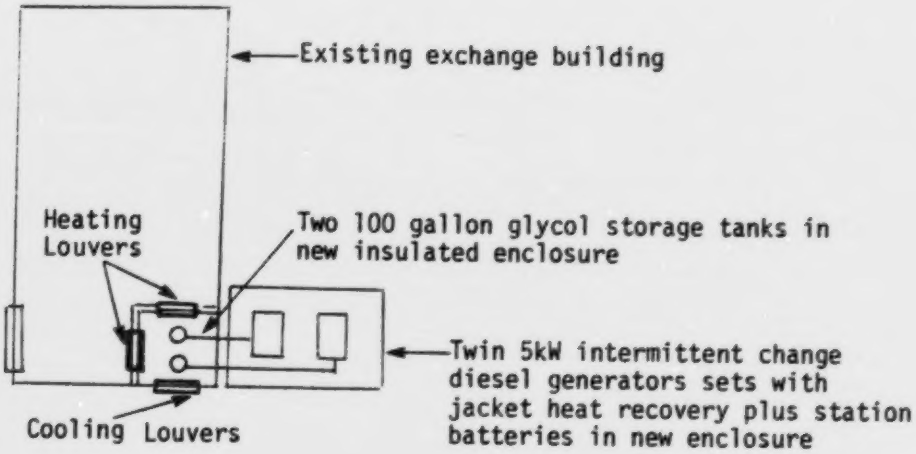
6.4.3 Battery Requirements

The recommended battery capacity is 1000 ampere-hours. Monitoring of the battery condition and life in several Newfoundland Telephone intermittent charge systems indicates that batteries normally used in microwave or satellite communications DC power supplies can withstand much deeper and more frequent discharges than was previously believed without reducing the life of the battery significantly.

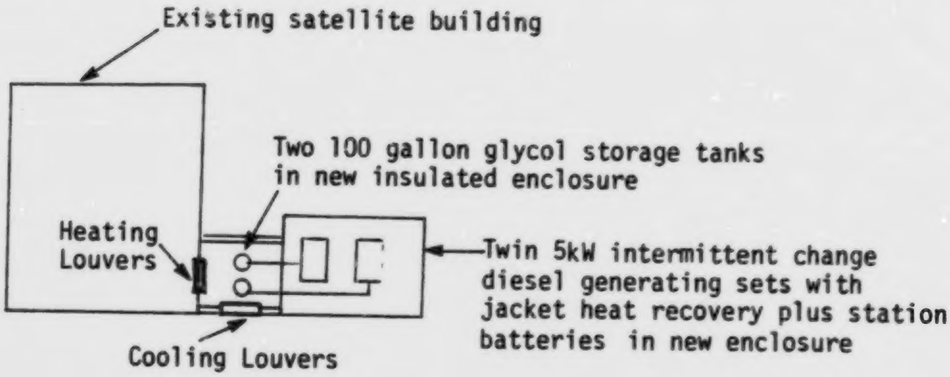
EXHIBIT 6.1

ALTERNATIVE PLANS FOR ADDITION OF AN INTERMITTENT CHARGE DIESEL GENERATING SYSTEM WITH HEAT RECOVERY AT MTC REMOTE COMMUNICATION SITES

EXCHANGE
SITE


Existing exchange building
Heating Louvers
Two 100 gallon glycol storage tanks in new insulated enclosure
Twin 5kW intermittent change diesel generators sets with jacket heat recovery plus station batteries in new enclosure
Cooling Louvers

TELSAT
SITE


Existing satellite building
Two 100 gallon glycol storage tanks in new insulated enclosure
Heating Louvers
Twin 5kW intermittent change diesel generating sets with jacket heat recovery plus station batteries in new enclosure
Cooling Louvers

Experience with similar batteries in solar photovoltaic systems also supports this. Consequently, the existing site batteries can be used.

6.4.4 Building Heating System

The recommended communications building heating system features two uninsulated 100 gallon storage tanks containing engine coolant located in an insulated enclosure built either inside an existing exchange building or between the engine room and an existing satellite/toll station building as shown in Figure 6.1. Each engine has its own coolant tank and coolant is circulated from the tank through the operating engine by the engine coolant pump. When the exchange or satellite building calls for heat, two DC powered louvered air circulation fans located in the tank enclosure/building wall are switched on, blowing warm air into the building until a set temperature is reached. If, because there is no building heating requirement (eg, in summer), the coolant tank enclosure temperature rises beyond a set limit, two louvers set one above the other in the outside wall of the enclosure are opened and the coolant tank is cooled by natural convection of outside air. A calculation showing that this method of cooling is adequate when there is no heating load is given in Appendix O. However, the control system features the capability of reducing engine load (eg, charging rate) if the cooling system temperature exceeds 95°C.

The DC heaters in the communications building are energized only when an absolute minimum set temperature is reached. These heaters would need to have a total capacity of only 1.6kW to supplement the waste heat recovery system. Baseboard convection heaters are recommended.

6.4.5 Exchange/Satellite Building Modifications

Removal of the DC power supply from the exchange or satellite/toll station building also removes the main source of excess heat in the building. The present 1/3 HP cooling fans in exchange buildings and room air conditioners in satellite buildings can therefore be replaced with small DC powered ventilation fans. In Northern Ontario, the number of degree days above 24°C, the upper temperature limit of some communications equipment, is zero; therefore no artificial air cooling (air conditioning) is required.

Tower lights should be converted to DC operation and controlled by a simple photo-cell. This technique has been successfully used by Newfoundland Telephone.

If the waveguide dehydrator is not already powered by DC it should be converted to DC.

The present building heating units may be left connected to the AC power supply for use only when maintenance personnel are present and the engine is running continuously.

The larger exchange buildings at remote MTC sites have already been thermally upgraded by the addition of extra insulation and general air tightening measures.

Appendix M shows that the design heat loss for these buildings is now not much larger than for the smaller satellite/toll station buildings. Upgrading of either type of building is not considered necessary during replacement of the current power systems with intermittent charge sets.

The larger exchange buildings appear to have more than adequate space to build the glycol coolant storage tank enclosure inside the building. This would reduce the cost of the enclosure. There is probably insufficient space in the satellite/toll station buildings (although removal of the DC power system and batteries would free up some space). At these sites, the glycol coolant tank enclosure would have to be built outside, between the engine building and the communications building. Location of the engine building (and tank enclosure if necessary) adjacent to either type of communication building will not require any major modifications to the building structure or introduce diesel fumes or other foreign matter into the building.

6.4.6 Control System

The basic generator set control sequence would be as follows:

- If the station battery drops below a set voltage or the communications building is below an absolute minimum temperature, then the engine starts.

- When the rectifier current drops below a set limit, and if the outside temperature is below freezing, and if the communications room is still below an absolute minimum temperature, then the 1.6 kW electric DC communications room heaters are energized.

- The engine continues to run only until the batteries are fully charged or the glycol coolant tank temperature reaches an upper set limit.

- During maintenance periods the control system can be manually overridden to provide continuous AC power to lights, wall plugs, and existing AC heaters.

- If the glycol storage tank temperature becomes greater than 95°C while the engine is running, then the charging rate is cut back to maintain the temperature at 95°C.

- The wave guide dehydrator and tower lights draw power from the batteries when required and are controlled by a pressure sensor and photocell respectively.

6.5 ESTIMATION OF FUEL CONSUMPTION AND ENGINE RUN TIME

Annual fuel consumption for A 5kW Series 2000 Cycle Charge unit at a remote communications site will be a function of the average DC load placed on the battery by the communications equipment plus any seasonal loads from the ventilation fans or back-up heating units.

The average communications load for microwave or satellite equipment, waveguide dehydrator and tower lights will vary from no more than 1 kW at an SRS site such as Angling Lake to about 1.5kW at a satellite/toll station to about 2.5 kW at a dual directional microwave exchange site such as Poplar Hill.

In summer (3 months), the average ventilation fan load will be no more than 250 to 500 watts, or about 800 kWh/year.

In winter, the back-up heating units will only be required when there is insufficient waste heat available. At an average communications load of 2.5kW, the diesel engines would produce an average waste heat output of (0.8)(2.5) = 2kW. At a design heat loss from an exchange communications building of 55 watts/°C, the waste heat recovery system would be able to keep the building above its minimum limit of 15°C on any day when the outside temperature was

$$15 - \frac{2000}{55} = -21°C.$$

In an exchange site,the additional heat required during the heating season will therefore be equal to 55 watts/°C times the number of degree days below -21°C. At a satellite/toll site where the average communication load would be about 1.5kW, and the design heat loss 37.5 watts/°C, the additional heat required during the heating season would be equal to 37.5 watts/°C times the number of degree days below -17°C.

The number of degree days below a given temperature in a given month is approximately equal to the number of days in the month times the difference between the given temperature and the monthly minimum. The monthly minimums for Big Trout Lake for the months of December, January, February and March are -24.5°C, -29.5°C, -28°C, and -22°C. All other monthly minimums are above -17°C. The additional heating load for exchange and satellite/toll sites are therefore approximately equal to:

Exchange site	800 kWh/yr
Satellite/toll site	1000 kWh/yr

This additional load will be met by a combination of DC electric heat plus the waste heat produced in generating it. Therefore, assuming that recoverable heat is approximately equal to 80% of electrical output, the actual additional electrical loads would be the above loads divided by 1.8, or:

Exchange site	450 kWh/yr
Satellite/toll site	550 kWh/yr

The total annual consumption at each site will be equal to a continuous load of 1.5 to 2.5 kW throughout the year plus 800 kWh for summer ventilation and 450 to 550 kWh for supplemental winter heating:

Exchange site	23,000 kWh/yr
Satellite/toll site	14,500 kWh/yr

Because the generator set is operating in an intermittent basis, the fuel required to provide this electrical load can be calculated from the Series 2000 engine specifications based on fuel consumption at a full load of 5 kW. Assuming a generator efficiency of 85%, and 1kW for engine room needs, engine power at 5kW electrical output is 9 BHP. From engine specifications in Appendix N, fuel consumption at 1700 rpm, 9 BHP is 0.43 lbs/BHP.hr. or 0.43 l/kWh electrical output. Therefore annual fuel consumption and engine running time at the two types of sites is estimated to be:

	Annual Fuel Consumption (l/yr)	Engine running Time (%)
Exchange site	10,000	52
Satellite/toll site	6,000	32

6.6 ECONOMIC ANALYSIS

6.6.1 Annual Operating Costs

As presented previously in Section 6.2, the estimated annual costs of operating and maintaining the present power systems at MTC remote communications sites is approximately $33,400. Table 6.4 provides a breakdown of this cost.

TABLE 6.4
MTC REMOTE COMMUNICATIONS SITES
CURRENT ANNUAL OPERATING COSTS

Fuel:	$11,400/yr
Routine Maintenance:	$10,000/yr
Trouble Shooting:	$12,000/yr
TOTAL:	$33,400/yr

At present there seems to be little difference in the fuel and maintenance costs between exchange and satellite/toll stations. This appears to be because the majority of exchange sites have uni-directional towers and draw no more communications load than the satellite equipment. The thermal efficiency of the larger exchange buildings is also higher than the satellite buildings.

Fuel consumption and costs have been shown in Section 6.5 to be about 10,000 litres ($6,200) for exchange sites and about 6,000 litres ($3,720) for satellite /toll stations.

The largest cost reductions resulting from the replacement of the present power systems with intermittent charge units would be expected to be seen in routine maintenance and trouble shooting. Routine maintenance is directly related to engine running time. With the intermittent charge system, the per cent engine time has been calculated (above) to be 52% at exchange sites, and 32% at satellite/toll stations. Consequently, the frequency of routine engine overhauls would be reduced proportionally. In addition, discussions with Bell Canada indicated that trouble shooting costs could be reduced by about 75% due to the increased reliability and reserve capacity of both the batteries and heating systems.

In contrast to the current annual operating and maintenance costs shown above in Table 6.4, the comparable annual costs using an intermittent charge system are estimated to be $14,400 for exchange sites and $9,920 for satellite/toll stations. Tables 6.5 and 6.6 show the estimated cost breakdown for exchange sites and satellite toll stations, respectively.

TABLE 6.5

MTC REMOTE COMMUNICATION SITES
ESTIMATED ANNUAL COSTS: INTERMITTENT CHARGE SYSTEM
- Exchange Site

Expense		Amount
1.	Fuel (10,000 l. @ 62¢)	$ 6,200
2.	Routine Maintenance (52% of Current)	$ 5,200
3.	Trouble shooting (25% of Current)	$ 3,000
	Total:	$14,400/year

TABLE 6.6
MTC REMOTE COMMUNICATIONS SITES
ESTIMATED ANNUAL COSTS: INTERMITTENT CHARGE SYSTEM
- Satellite/Toll Station

Expense		Amount
1.	Fuel (6000 l. @ 60¢)	$ 3,720
2.	Routine Maintenance (32% or current)	$ 3,200
3.	Trouble Shooting (25% of Current)	$ 3,000
	Total:	$ 9,920

Annual fuel and maintenance savings are therefore estimated to be $19,000 for an exchange site and $23,480 for a satellite/toll station.

6.6.2 Capital Cost

The installed cost of a 5kW Mechron Energy Limited Cycle Charge Series 2000 generating set, new engine room, heat recovery and storage equipment, and modifications to the exchange or satellite/toll building is estimated by Mechron to be $87,700. Table 6.7 provides a cost breakdown.

TABLE 6.7
INSTALLED CAPITAL COST
- Mechron Cycle Charge Series 2000

Engine enclosure (including installation of two Series 2000 units)	$24,000
Two (2) 5kW Cycle Charge Series 2000 generator sets	$38,000
Station batteries	(assume existing site batteries used)
Control system for Cycle Charge sets	$ 8,000
Field installation of above (crew & transportation)	$ 9,000
Modifications to existing buildings (DC fans, heaters, etc.)	$ 700
Engine heat recovery and storage equipment (tanks, fans, louvers, etc.)	$ 3,500
Heat storage enclosure	$ 3,500
Transformer for station AC	$ 1,000
TOTAL:	$87,700

6.6.3 Cost Summary

Based on the above calculations, the simple payback period for installation of a cycle charge series 2000 unit is 4.6 years for an exchange site and 3.7 years for a satellite/toll station.

Table 6.8 presents a comparison of the present value of maintaining the current diesel generating sets at MTC remote communications sites versus replacing them with Mechron "cycle-charge" 2000 series units.

As shown in Table 6.8 the present value of the cost of continuing to operate a conventional diesel generating set is $537,000. This contrasts sharply with a cost of $288,200 for operating a cycle charge 2000 unit at a microwave exchange site and $221,500 at a satellite/toll station. Consequently, the present value of the savings resulting from the installation of the Mechron "cycle-charge" 2000 series units is $248,800 for an exchange site and $315,500 for a satellite toll station.

The total potential savings for the 11 MTC remote sites over a 20 year period is approximately $3,137,000.

TABLE 6.8

PRESENT VALUE ANALYSIS OF MAINTAINING CURRENT DIESEL GENERATING SETS AT MTC REMOTE COMMUNICATIONS SITES VERSUS REPLACING THEM WITH CYCLE CHARGE UNITS

Discount Rate: 7%
Fuel Inflation Rate: 5%
Maintenance and Equipment Inflation Rate: 4%
Time Period: 20 years

	Existing Sets	**Cycle Charge 2000 Sets** (Microwave exchange)	**Cycle Charge 2000 Sets** (Satellite toll)
Expected Life	20 years	40 years	40 years
Initial Cost (yr 1)	$ 0	$ 87,700	$87,700
Replacement Cost (yr 10)	$48,900	$ 0	$ 0
Salvage Value (25%) (yr 20)	($9,200)	($12,400)	($12,400)
Maintenance Costs	$318,100	$118,600	$89,600
Fuel Costs	$179,200	$94,300	$56,600
Total Cost	$537,000	$288,200	$221,500

6.7 RECOMMENDED ACTION

Based on the preceding assessment, it is evident that intermittent charge diesel generating sets, such as the Mechron series 2000 system, present a very attractive option for reducing fuel and maintenance costs in MTC remote communications sites.

One demonstration of the Mechron "cycle charge" series 2000 system is currently planned for a Bell Canada repeater site north of Sudbury. Subject to the performance results derived from this demonstration, the results shown in this assessment show that further implementation leading to the possible gradual replacement of all existing conventional sets is warranted.

One of the most difficult aspects of using intermittent charge generating systems in remote MTC communications sites would be the split agency responsibilities - especially at the Telsat sites. Replacing the present power sets at satellite stations with intermittent charge sets would involve changes to the Telsat equipment (DC power supply, heating and cooling equipment). However, because Bell Canada/MTC currently pay for power system fuel and maintenance, Telsat would get no benefit from the changes. Telsat would probably only be interested if responsibility for the batteries and DC power supply was switched to Bell Canada and reliable AC and DC power could be on hand from Bell for less than they pay now for AC power. The arrangements at microwave sites would be less difficult but would still have to involve co-operation and financial transfers between the communications and power system divisions of Bell.

Consequently, it is recommended that the Ministry of Energy, together with MTC, commence discussions with Telsat Canada and Bell Canada to establish new and equitable cost/responsibility sharing arrangements on communications power supply.

SECTION 7

USE OF PHOTOVOLTAICS TO REDUCE FUEL CONSUMPTION IN INTERMITTENT CHARGE DIESEL GENERATING SYSTEMS FOR REMOTE COMMUNICATIONS FACILITIES

7.1 INTRODUCTION

Section 6 showed that significant reductions in fuel and maintenance costs can be achieved in MTC remote communications sites by replacing the current conventional diesel power systems with the Mechron Energy Ltd. "Cycle Charge" diesel system.

Fuel consumption in the "Cycle Charge" system is, however, still about 7.5 litres/year per watt of communications load. This consumption can be reduced even further through the use of wind or photovoltaic generated power. Wind and photovoltaic systems are both well suited for use with a "Cycle Charge" system:

- sufficient battery capacity already exists in the "Cycle Charge" system
- the "cycle charge" control system can be used to control the wind or solar input
- both solar and wind power generating systems operate most effeciently when producing DC power.

There are several reasons why a photovoltaic system is a better match to a "Cycle Charge" generating set than a wind system in the Northern Ontario environment. First, a large percentage of the winter heating load in the communications building can be met with waste heat from the diesel engine. If power was provided from a renewable source in winter, the engine would run less frequently, the waste heat available would be lower, and more heating would have to be supplied electrically. The renewable energy source would, in effect, have to provide electricity at a cost lower than oil cogenerated electricity and heat to be cost effective. On the other hand, meeting the summer communications and cooling load totally with a renewable generating system would allow the diesel engine to remain off most of the time. The renewable source would therefore only have to compete against oil generated electricity. A solar source which peaks in the summer, is therefore preferable to a wind source which tends to peak in the winter.

Second, the wind regime in non-coastal Northern Ontario will not produce high wind turbine generator contributions. Mean wind speeds are in the order of only 15 km/hr. The solar regime, on the other hand is relatively good with long clear periods during the summer and winter seasons.

7.2 CALCULATION OF FUEL SAVINGS

To estimate the fuel savings that could be achieved through the use of a hybrid photovoltaic and intermittent charge diesel system, it is first necessary to:

- Determine optimum array orientation and estimate the amount of radiation available
- Determine the potential for energy savings
- Determine the optimum array size

7.2.1 Optimum Array Orientation and Solar Radiation Available

As was discussed above, the value as well as the amount of solar energy available during the winter months is lower than during the summer. This is because in winter diesel fuel can be used to provide both electrical power and heat. The array should therefore be tilted to maximize solar energy output during the non-heating season and provide a relatively constant daily output during this period. The tilt angle which meets these requirements is about 30^0 to the horizontal. Although this will result in some snow build up in the winter, as is shown below, the reduction in energy savings will not be large.

Table 7.1 shows the calculation of the amount of solar radiation $H_t(MJ/m^2.day)$ falling on a square metre of south facing PV module titled at 30° to the horizontal for a average day in each month of the year. The solar radiation data used as the basis for the calculation are the mean for three sites close to Northern Ontario for which there is measured monthly average radiation on a horizontal surface (H) and monthly average clearness indices (K_t.) The three sites used were Kapuskasing, Winnipeg, and Churchill. The method used to determine solar radiation was that given by Duffie and Beckman (1980).

The average monthly (30.5 days) output from a PV array with area A m^2 and average solar efficiency e_s will be:

relocate 30.5 e_s A H_t (MJ/mo)

7.2.2 Potential for Energy Savings

The actual energy savings that will be obtained each month from using a PV array as a fuel saver with a diesel generator that has waste heat recovery will depend not only on the array area and the electrical load but also the heating load of the communications building. The savings can be calculated by making monthly energy balances on the total system. Equations for estimating monthly energy savings are derived in Appendix P.

7.2.3 Optimum Array Size

The optimum size of a PV array will be one which is large enough to provide reasonable solar savings but not so large that it provides excess power in the summer or increases the number of months during which the PV array competes against the waste heat contribution. The true optimum could be obtained by deriving a generalised formula for annual fuel savings based on the monthly energy balance equations given in Appendix P, and then determining the array area which is equivalent to maximum savings. An approximate optimum, however, will be an area which will just meet the communications equipment load during the summer months.

TABLE 7.1

SOLAR RADIATION ON A SOUTH FACING SURFACE TILTED AT 30° TO THE HORIZONTAL AT LATITUDE 53°N IN NORTHERN ONTARIO

Month	*Daily Radiation on a Horizontal Surface H (MJ/m^2)	Daily Extra-Terrestrial Radiation H_o (MJ/m^2)	*Clearness Index K_t	Ground Reflectance Factor	Daily Radiation on a 30° tilted Surface H_t (MJ/m^2)
JAN	4.3	7.2	0.59	0.7	11.3
FEB	7.9	12.6	0.63	0.7	15.1
MAR	13.7	20.6	0.67	0.7	20.0
APR	17.5	29.9	0.58	0.5	21.1
MAY	20.0	37.5	0.54	0.3	20.2
JUN	21.4	40.9	0.52	0.2	20.5
JUL	21.7	39.2	0.55	0.2	21.9
AUG	17.5	32.9	0.53	0.2	19.1
SEP	11.3	23.7	0.47	0.2	14.7
OCT	6.7	14.9	0.44	0.2	10.8
NOV	3.6	8.5	0.43	0.5	8.0
DEC	2.9	5.9	0.48	0.7	8.2

*Northern Ontario values are assumed to be the average of those for Kaspuskasing, Churchill, and Winnipeg.

7.3 SAMPLE CALCULATION OF MONTHLY AND ANNUAL FUEL SAVINGS FOR A TYPICAL MICROWAVE EXCHANGE SITE

To calculate monthly and annual fuel savings from a sample PV installation it is necessary to:

- identify the base communications load and the building heating and cooling loads
- choose the size of the array
- calculate monthly/annual energy savings
- calculate monthly/annual fuel savings

7.3.1 Base Load

Using a typical microwave exchange site as an example, the base communications load is 800 watts (see Section 6). About 90% of this energy will be converted into heat in the radio room. In addition there will be a 500 watt load from the tower lights. The base load including tower lights (B) will therefore be 1300 watts, and the fraction of this load (f) converted into heat will be about 0.5.

The building heating load (X) will be about 55 watts/°C, (from Section 6) or 4.75 MJ/Degree day.

7.3.2 Size of Array

Current photovoltaic cell conversion efficiencies range from about 4% for amorphous silicon cells to almost 18% for the latest generation of single crystal silicon cells (Bolton, 1982; Blakers et al, 1984). Most cells currently suitable for communciations power systems have an efficiency in the 10 to 12% range. Allowing for array losses due to cell spacing, a slightly higher efficiency in winter than in summer, and a drop of about 2% in efficiency over the life of a cell, the average lifetime efficiency of current PV modules may be conservatively assumed to be about 7%.

The area (A) of PV array that would meet an average load of 800 watts during July assuming an average solar efficiency of 7% is 45 square metres.

$$A = \frac{0.8 \times 24 \times 3.6}{0.07 \times 21.9} = 45\text{m2}$$

where:

0.8 = communications equipment load (kW)
24 = number of hours/day
3.6 = MJ per kWh
0.07 = solar efficiency of PV array
21.9 = July daily radiation m MJ/m^2 on a 30° tilted surface
(from Table 7.1)

7.3.3 Monthly/Annual Energy Savings

Monthly energy savings for the typical microwave exchange site, calculated using the equations derived in Appendix P, are shown in Table 7.2. Total annual energy savings are 15,210 MJ (4200kWh) with the greatest energy savings being achieved during the months of May through August.

Because of the low winter contribution, a maximum of 2600 MJ/yr. or only 17% of the energy, would be lost due to snow build up.

If 10% efficient PV modules were available, the size of array required would be only 31 m^2. The total energy savings produced, however, would be the same.

7.3.4 Monthly/Annual Fuel Savings

The calculated energy savings can be converted to fuel savings through application of the following formula:

$$\underset{\text{(litres/month)}}{\text{Fuel Savings}} = \frac{\text{Energy Savings(MJ)}}{3.6 \times 10.6 \times e_d}$$

Where:

3.6 = MJ per kWh

10.6 = fuel energy value (kW) per litre

e_d = electrical conversion efficiency (0.33)

Monthly and annual fuel savings are shown in Table 7.2 and the total annual savings from using the array are estimated to be 1,207 l/yr.

TABLE 7.2

FUEL SAVINGS FROM USING A $45 m^2$ 7% EFFICIENT PHOTOVOLTAIC ARRAY TILTED AT 30° TO THE HORIZONTAL WITH A CYCLE CHARGE DIESEL GENERATOR SYSTEM WHICH HAS AN ELECTRICAL CONVERSION EFFICIENCY OF 33% AND JACKET WASTE HEAT RECOVERY EFFICIENCY OF 24%

Month	Monthly Radiation on a 30° tilted surface H_m (MJ/m^2)	Degree Days below 18°C	Heating Load X (MJ/mo)	Monthly Energy Savings (MJ/mo)	Monthly Fuel Savings (litre/mo)
JAN	350	1317	6260	640	51
FEB	423	1113	5290	770	61
MAR	620	1010	4800	1130	90
APR	633	655	3110	1150	91
MAY	606	418	1990	1910	152
JUNE	615	188	890	1940	154
JULY	679	86	410	2140	170
AUG	592	127	600	1860	148
SEP	441	298	1420	1390	110
OCT	335	504	2390	1060	84
NOV	240	803	3810	760	60
DEC	254	1175	5580	460	37
TOTAL		7699		15,210	1,207

Site Loads: Base commuinication load: 800 watts
Tower light load: 500 watts
Fraction of communications and tower light load converted into heat: 0.5
Heating load: 4.75 MJ/Deg.day

7.4 COST EFFECTIVENESS

The key factor in determining the cost effectiveness of using photovoltaics is the cost per unit energy output. This is usually expressed as cost per peak watt. A peak watt is defined as the cell output in watts when irradiated at 1000 watts/m^2. The current cost of PV modules suitable for communications applications is about \$10 per watt. For a 7% efficient module the cost per unit area is therefore equal to:

$$\$10 \times 0.07 \times 1000 \text{ or } \$700/m^2$$

For a 10% efficient module, the cost would be \$1000/m^2.

At \$10 per peak watt, therefore, the cost of the PV array for the above example would be \$31,500 regardless of cell efficiency. The annual fuel savings would be 1200 litres.

Assuming a current fuel price of 62¢/litre, a fuel inflation rate of 5%, a discount rate of 7%, and a time period of 20 years, the net present value of these fuel savings is \$11,700. At current array and fuel costs, therefore, the PV system is not an economic proposition. If no maintenance costs are allowed for, the array price at which the PV system will become cost effective is \$11,700, which is equivalent to \$3.70 per peak watt.

Recent reviews of the status of PV technology (Bolton, 1983) and discussions with National Research Council, indicate that the current single crystal silicon cells will be replaced by mass produced silicon ribbon cells, amorphous silcon cells, and other non silicon cells such as CdS/Cu_2S and GaAs cells over the next 3-5 years. Through either higher efficiencies or lower cost production techniques, the cost per peak watt is expected to drop to below $4 during this period. PV systems for fuel saving applications in cycle charge diesel communications sites are therefore predicted to be cost effective within 5 to 10 years.

7.5 RECOMMENDED ACTION

At the present time, PV does not present an attractive investment opportunity for MTC. However, as shown, a well designed PV array can complement the fuel savings of an intermittent charge diesel system, when used in a remote Northern Ontario communications facility. Further, significant cost reductions in the manufacturing of PV arrays are expected within the next 5-10 years. Consequently, it is recommended that the Ministry of Energy consider the installation of one demonstration PV array as part of its technology development and demonstration mandate.

The most appropriate demonstration remote communications site woud be one where the base communications load is small; this would keep the cost of the demonstration array to a minimum. The smallest communications load among the MTC remote communications sites in Angling Lake which has an 80 watt SRS system operated from Big Trout Lake. Because of the small communications load and lower tower light and cooling fan loads at Angling Lake, the PV array could be sized to meet all site power requirements during the summer. For example, in the month of July, an 11.25 m^2, 7% effecient PV array would entirely meet average summer load of 200 watts.

Therefore, it is recommended that if and when, the current conventional Ball generating sets are replaced at Angling Lake, by a 5kW "Cycle Charge" system, the installation of a demonstration PV array should be considered by the Ministry of Energy.

REFERENCES

Air Sealing Homes, 1984

"Air Sealing Homes for Energy Conservation" Second Draft, Energy, Mines & Resources Canada, 1984 ISBN 0-662-13053-7, Catalogue No. M92-6/1984 E;

BEG, 1983

"Industrial Service Doors - A Review"
Building Engineering Group, Waterloo, Ontario for Buildings Energy Technology Transfer Program, Energy Mines & Resources Canada, December 1983

Blakers A.W. et al, 1984

"18-Percent-Efficient Terrestrial Silicon Solar Cells"
A.W. Blakers et al, IEEE Electron Device Newsletter, Vol. EDL-5, No 1, January, 1984

Bolton, 1983

"Solar Cells - A Technology Assessment"
James R. Bolton, Solar Energy Vol. 31, No 5, pp 483-502, 1983

Duffie & Beckman, 1980

"Solar Engineering of Thermal Processes,
John A. Duffie and William A. Beckman, John Wiley, 1980

Newfoundland Telephone, 1982

"Four Mile Pond Cycle Charge Experiment"
Final Report, D.C. Tilley and J.T. Wadden,
Newfoundland Telephone, November 1982

Ontario Hydro, 1983

"Remote Community Wind/Diesel Study"
Ontario Hydro Design & Development Division
Report No 83105, March 1983

Saskatchewan Research Council, 1983

"An Evaluation of Computer Programs for House Energy Modelling: Volume 7, An Interim Report on the Evaluation of ECAP, HOTCAN, and the DEGREE DAY METHOD" Saskatchewan Research Council, November 1983

Assessment of Renewable Energy and Conservation Opportunities for Ministry of Transportation and Communications Remote Facilities

Appendices

Ontario

Ministry
of
Energy

Honourable
George Ashe
Minister

Energy
Ontario

ASSESSMENT OF RENEWABLE ENERGY
and
CONSERVATION OPPORTUNITIES FOR
MINISTRY OF TRANSPORTATION
AND COMMUNICATIONS
REMOTE FACILITIES
Appendices

Prepared for
Ontario Ministry of Energy

by
Marbek Resource Consultants Ltd.

May, 1984

LIST OF APPENDICES

APPENDIX A Bearskin Lake Airport Energy Audit Calculations

APPENDIX B Calculation of Wind Infiltration Losses in Bearskin Lake Airport Garage

APPENDIX C Calculation of Fuel Consumption, Recoverable Heat, and Equipment Size for Diesel Generating Sets

APPENDIX D Specifications for a 15kW Diesel Generating Set with Heat Recovery for Remote Airport Power and Garage Heating

APPENDIX E Specifications for a Dual 50kW Prime Power Diesel Generating System with Heat Recovery for Remote Airport Power and Garage Heating

APPENDIX F Lansdowne House Airport Office/Accommodation Building: Current MTC Layout and Specifications

APPENDIX G Lansdowne House Airport Office Accommodation Building: Modified Energy Efficient Layout, Specifications, and Construction Schedule

APPENDIX H Heat Loss Calculations for Lansdowne House Airport Office/Accommodation Building

APPENDIX I Examples of Super Energy Efficient Design Techniques for Future MTC Airport Office/Accommodation Buildings

APPENDIX J Winisk Airport Energy Audit Calculations

APPENDIX K	Estimation of Wind Turbine Energy Contribution
APPENDIX L	Slate Falls Communications Power System Energy Audit Calculations
APPENDIX M	Design Heat Loss Calculation for Remote Communications Buildings in Northern Ontario
APPENDIX N	Mechron Energy Limited Series 2000 Cycle Change Diesel Generating System
APPENDIX O	Effectiveness of Glycol Storage Tank Heat Recovery/ Cooling System with a Cycle Change Diesel Generating System
APPENDIX P	Method Used to Calculate Monthly Energy Savings from Using a Photovoltaic Array with a Diesel Generating Set that has Jacket Heat Recovery
APPENDIX Q	Bell Canada Expenditures at MTC Remote Communications Sites: 1981 through 1983

APPENDIX A

BEARSKIN LAKE AIRPORT
ENERGY AUDIT CALCULATIONS

APPENDIX A

BEARSKIN LAKE AIRPORT ENERGY AUDIT CALCULATIONS

Assumptions: Design Temperature and Degree Days:

The calculation of space heating loads requires data related to:

- Interior design temperatures
- External design temperature
- Degree days below interior design temperatures

The following assumptions are made.

1.1 Interior design temperatures. These are assumed to be as follows:

- House	22°C
- Garage	10°C
- Waiting Room	10°C

1.2 Exterior design temperatures: The following design temperatures and degree days were used for Bearskin Lake, taken from Canadian Climate normals for Big Trout Lake:

Design Temperature:	-38°C
Average Heating Season Temperature:	-10°C
Degree Days below 22°C:	8500
Degree Days below 10°C:	5000

Bearskin Lake Airport House:

	Construction	Thermal Resistance (RSI) walls/°C/m^2	Number	Dimensions	Area
Doors	Wood(75mm)	0.7	2	2m X 1m	4m^2
Windows	double pane	0.7	6	1.25m X 1m	7m^2
Walls (including crawlspace excluding doors & windows)	wood frame fibreglass insulation(90mm) plywood panelling	2.4	2 2	7.5m X 3m 12.5m X 3m	110m^2
Ceiling	wood frame fibreglass: insulation (140mm) ceiling tile	3.8	1	7.5mX12.5m	90m^2
Floor	dirt	0.4	1	7.5mX12.5m	90m^2

$$\textbf{CONDUCTION HEAT LOSS} = \frac{\textbf{Area X Design Temperature Difference}}{\textbf{RSI}} \text{ (watts)}$$

Design temperature difference (floor) = 22 - 2 = 20°C

Design temperature difference (other) = 22 - (-38) = 60°C

Therefore: Conduction heat loss =

$$\frac{60 \times 11}{0.7} + \frac{60 \times 110}{2.4} + \frac{60 \times 90}{3.8} + \frac{20 \times 90}{0.4} = 9610 \text{ watts}$$

INFILTRATION HEAT LOSS = 0.335 X House volume X Design temperature difference X number of air changes per hour (watts)

House volume = 273m^3

The number of air changes per hour was assumed to be that of a house of average air tightness ie, 0.75.

Therefore: **Infiltration heat loss** = 0.335 X 273 X 60 X 0.75
= 3840 watts

Therefore: **Total design heat loss** = 9610 + 4120
= 13,730 watts

Annual heating load = $\frac{\text{Design heat loss X 24}}{\text{Design temperature difference}}$

= $\frac{13,730 \text{ X } 24}{60}$

= 5500 Wh/Degree Day

= 5500 X 8500

= 46,680 kWh/year

Assuming a 65% fuel burner efficiency and an oil heating value of 10.6 kWh/litre;

Annual fuel consumption = $\frac{46,680}{10.6 \text{ X } 0.65}$

= 6800 litres

Bearskin Lake Airport Garage (Heated portion):

	Construction	Thermal Resistance (RSI) walls/°C/m^2	Number	Dimensions	Area
Sliding doors	wood frame fibreglass insulation (90mm)	2.4	2	3.5m X 5m	35m^2
Walls (excluding sliding doors)	wood frame fibreglass insulation (90mm) plywood (2)	2.4	2 2	15m X 5m 8.5m X 5m	200m^2
Ceiling	wood frame fibreglass insulation (140mm) plywood	3.8	1	15m X 8.5m	130m^2
Floor	cement pad	0.7	1	15m X 8.5m	130m^2

CONDUCTION HEAT LOSS = $\frac{\textbf{Area Design Temperature Difference}}{\textbf{RSI}}$ **(watts)**

Design temperature difference (floor) = 10 - 2 = 8^{0}C

Design temperature difference (other) = 10 - (-38^{0}) = 48^{0}C

Therefore: Conduction heat loss =

$$\frac{48 \text{ X } 35}{2.4} + \frac{48 \text{ X } 200}{2.4} + \frac{48 \text{ X } 130}{3.8} + \frac{8 \text{ X } 130}{0.7}$$

= 7830 watts

INFILTRATION HEAT LOSS = 0.335 X Garage volume X Design temperature difference X number of air changes per hour (watts)

Garage volume = 637m^3

The number of air changes per hour was assumed to be about 4, considering the high leakage through the sliding doors.

Therefore: **Infiltration heat loss** = 0.335 X 640 X 48 X 4
= 41,000 watts

Therefore: **Total design heat loss** = 7830 + 41,000
= 48,830 watts

Annual heating load $= \frac{\text{Design Heat Loss X 24}}{\text{Design Temperature Difference}}$

$= \frac{48{,}830 \times 24}{48}$

= 24,400 Wh/Degree Day

= 24,400 X 5000

= 122,000 kWh/year

Assuming a 65% fuel burner efficiency and an oil heating value of 10.6 kWh/litre;

Annual fuel consumption $= \frac{122{,}000}{10.6 \times 0.65}$

= 17,700 litres/year

Bearskin Lake Airport Waiting Room:

	Construction	Thermal Resistance (RSI) walls/°C/m^2	Number	Dimensions	Area
Doors	Wood (75mm)	0.7	2	2m X 1m	4m^2
Windows	Double pane	0.7	3	1.5m X 0.7m	3m^2
Walls (excluding doors & windows)	Wood frame fibreglass insulation(90mm) plywood (2)	2.4	2 2	6m X 2.5m 3.3m X 2.5m	40m^2
Ceiling	Wood frame fibreglass insulation (90mm) plywood	2.4	1	6m X 3.3m	20m^2
Floor	Wood frame plywood	0.4	1	6m X 3.3m	20m^2

$$\textbf{CONDUCTION HEAT LOSS} = \frac{\text{Area X Design temperature difference}}{\text{RSI}} \text{(watts)}$$

Design temperature difference = 10 - (-38) = 48°C

Therefore: Conduction heat loss =

$$\frac{48 \text{ X } 7}{0.7} + \frac{48 \text{ X } 60}{2.4} + \frac{48 \text{ X } 20}{0.4}$$

= 6475 watts

INFILTRATION HEAT LOSS = 0.335 X Building volume (m^2)
X design temperature difference (°C)
X Number of air changes per hour (watts)

Waiting Room volume = 49m^3

The number of air changes per hour was considered to be much higher than an average house because of the warped and leaky doors. A value of 1.25 was used.

Therefore: **Infiltration heat loss** = 0.335 X 49 X 48 X 1.25
= 985 watts

Total design heat loss = 6475 + 985
= 7460 watts

Annual heating load $= \frac{\text{Design heat loss X 24}}{\text{Design temperature difference}}$

$= \frac{7460 \text{ X } 24}{48}$

= 3730 Wh/degree day

= 3730 X 5000

= 18,650 kWh/year

Assuming a 50% fuel stove efficiency and an oil heating value of 10.6 kWh/litre:

Annual fuel consumption $= \frac{18,650}{10.6 \text{ X } 0.5}$

= 3500 litres/year

Bearskin Lake Airport Power Generator:

Generator set rating:	Pritchard 15 kW, 15 KVA, 1.0 Power factor, 1800 rpm. 120/240 volt, 60Hz.
Engine:	Perkins 4-108 4 cycle, 4 stroke, natural aspirated, liquid cooled with mounted radiator and fan, rated 26 HP at 1800 rpm
Alternator:	Brown Boveri model 295, rated 18.7 KW, 23.4 KVA, 0.8 power factor, 120/240 single phase

Measured load at 9:00 am was 34 amp in leg 1 and 50 amp in leg 2 for a total of 84 amps.

At 120 volts this is equivalent to $\frac{84 \text{ X } 120}{1000}$

= 10 KVA
= 8kW at 0.8 Power Factor

This engine is therefore loaded to 53% of its capacity.

Assuming an 80% generator efficiency because of the low load:

$$\text{Engine shaft horse power} = \frac{8}{0.746 \times 0.80}$$

$$= 13.4 \text{ SHP}$$

Assuming a fuel consumption of 0.47 lbs/BHP/hour because of low load:

Engine fuel consumption = 13.5 X 0.47
= 6.345 lbs/hr.
= 3.4 litres/hr.

At a fuel heat value of 10.6 kWh/l then the total heat production

= 10.6 X 3.4
= 37 kW

Therefore, the generator set thermal efficiency = 8/37 = 22%

With a generator efficiency of 80%
Then: Engine thermal efficiency = 28%
Then: Engine losses = 72%
= 26kW

Assuming that about 16% of the heat is lost through radiation and lube oil heat loss, about 20kW of heat are potentially recoverable from the exhaust and radiator.

At 50% set loading, radiator and exhaust cooling losses are usually about equal ie 10kW each.

Assuming that 70% of exhaust heat and 100% of radiator heat are recoverable, then the practical amount of recoverable heat is about 17kW (58,000 BTU/hr) (60MJ/hr)

APPENDIX B

CALCULATION OF WIND INFILTRATION LOSSES IN BEARSKIN LAKE AIRPORT GARAGE

APPENDIX B

CALCULATION OF WIND INFILTRATION LOSSES IN BEARSKIN LAKE AIRPORT GARAGE

From BEG, 1983, the annual heat loss due to infiltration through an industrial door is as follows:

$$q_A = p_o \, c_p \, C_D \, A_e \, (T_i - T_o) \overset{5}{\underset{1}{}} \; C_w^{\frac{1}{2}} \; V_w \; t_w$$

where q_A = annual heat loss (J/year)

p_o = air density at T_o (Kg/m^3)

c_p = specific heat of air (J/kg.°C)

C_D = discharge coefficient for orifice flow (0.65)

A_e = equivalent infiltration area - a function of crack area and open door time (m^2)

T_i = mean inside temperature (°C)

T_o = mean outside temperature during the heating season (°C)

C_w = wind coefficient from direction w (C_1=0.25, C_2=0.4, C_3=0.5, C_4=0.4, C_5=0.25)

V_w = mean wind speed from direction w during the heating season (m/hr)

t_w = wind duration from direction w during the heating season (hrs)

w = the five wind directions contributing to infiltration (e.g. N, NNW, NW, WNW, and W for a NW facing door)

At Bearskin Lake airport, the garage doors have an area of 17.5 m^2 each. Assuming that the doors are open for 2 hours each week (25 min. per working day) and that the crack width is about 25mm (1"), the effective area A_e is equal to:

$$A_e = \frac{\text{Door Area x hours open + Crack area x hours closed}}{\text{Total hours}}$$

$$= \frac{17.5 \times 2 + 0.425 \times 166}{168}$$

$$= 0.63 \text{ m}^2$$

Weather data for Bearskin Lake may be assumed to be the same as for Big Trout Lake given in Table B.1. Inside temperature T_i may be assumed to be +10°C.

Door #1 (Facing NE):

Contributing Wind Direction (w)	Duration t_w(hrs)	Speed v_w(m/hr)	C_w	$C_w^{\frac{1}{2}} t_w v_w$ (m)
N	429	16,400	0.25	3,520,000
NNE	213	16,400	0.4	2,210,000
NE	246	14,700	0.5	2,560,000
ENE	194	14,700	0.4	1,800,000
E	323	13,900	0.25	2,240,000
				12,330,000

Using p_o = 1.29 kg/m^2 & c_p = 1025 J/kg°C.

Heating season infiltration heat loss

$$q_A = 1.29 \times 1025 \times 0.65 \times 0.63 \times [10-(-10)] \times 12{,}330{,}000 \quad \text{(J/yr)}$$

$$= 134 \text{ GJ/yr}$$

$$= 37{,}100 \text{ kWh/yr}$$

TABLE B.1

BIG TROUT LAKE WEATHER DATA

FOR HEATING SEASON (OCT 1 TO MAY 30)

Degree Days below 18°C = 7000

Degree Days below 0°C = 2913

Mean Temperature = -10°C

Compass Wind Direction	Wind Speed (km/hr)	Duration (hrs)
N	16.4	429
NNE	16.4	213
NE	14.7	246
ENE	14.7	194
E	13.9	323
ESE	16.0	130
SE	15.6	245
SSE	14.8	289
S	12.7	395
SSW	12.8	277
SW	12.5	350
WSW	13.7	308
W	14.5	563
WNW	16.4	559
NW	16.6	657
NNW	18.4	414
Calm	0	228

Source: Canadian Climate Normals Volume 4 1951-1980.

Door #2 (Facing SW):

Contributing Wind Direction (w)	Duration t_w(hrs)	Speed v_w(m/hr)	C_w	$C_w^{\frac{1}{2}} t_w v_w$ (m)
S	395	12,700	0.25	2,510,000
SSW	277	12,800	0.4	2,240,000
SW	350	12,500	0.5	3,090,000
WSW	308	13,700	0.4	2,670,000
W	563	14,500	0.25	4,080,000
				14,590,000

Heating season infiltration heat loss

q_A = 158 GJ/yr

= 43,900 kWh/yr

Total infiltration loss (Doors #1 & 2) = 81,000 kWh/hr

APPENDIX C

CALCULATION OF FUEL CONSUMPTION, RECOVERABLE HEAT, AND EQUIPMENT SIZE FOR DIESEL GENERATING SETS

APPENDIX C

CALCULATION OF FUEL CONSUMPTION, RECOVERABLE HEAT AND EQUIPMENT SIZE FOR DIESEL GENERATING SETS

Engine power output (kW) =

$$\frac{\text{Electrical load (kW)} + \text{Radiator fan load (kW)}}{\text{Generator Efficiency}}$$

$$\textbf{Engine loading} = \frac{\text{Engine power output (kW)}}{\text{Rated engine size (kW)}}$$

Generator efficiencies generally vary from between 60% at no load to 85% at full load.

In a typical naturally aspirated diesel engine, fuel consumption per unit engine power output is a function of engine loading as follows:

ENGINE LOADING	**TYPICAL FUEL CONSUMPTION**	
	(kg/hr.kW)	(lbs/hr.BHP)
100%	0.24	0.40
50%	0.27	0.45
25%	0.35	0.58
12.5%	0.43	0.72

Assuming a fuel oil density of 0.85kg/l:

Engine fuel use (l/hr) = 1.18 x Fuel consumption (kg/hr.kW) x Engine Power Output (kW)

Assuming a fuel oil energy value of 38.2 MJ/l:

Engine fuel energy (MJ/hr) = 38.2 x Engine fuel use (l/hr)

This fuel energy is distributed between the following:

Engine power output
Exhaust gas heat
Jacket coolant heat
Jacket radiation heat losses

These energy fractions may be calculated as follows:

Energy power output (MJ/hr) = 3.6 Engine power output (kW)

Exhaust gas heat (MJ/hr) = 0.0011 (MJ/kg.°C)
x Exhaust gas rate (kg/hr)
x (Exhaust gas temperature (°C)
- Air temperature (°C))

Jacket coolant heat (MJ/hr) + Jacket radiation losses (MJ/hr)
= Engine fuel energy (MJ/hr)
- Engine power output (MJ/hr)
- Exhaust gas heat (MJ/hr)

As the engine loading falls, the fuel energy distribution typically changes as shown in Figure C.1. Diesel engine manufacturers usually provide information on fuel consumption, and exhaust flow and temperature at various engine loadings in their product specifications which allows calculation of the energy distribution at any loading.

The actual amount of exhaust heat that is recoverable is dependent on the effectiveness of the exhaust heat recovery heat exchanger and the exchanger coolant temperature.

Recoverable exhaust heat (MJ/hr) =

.0011 (MJ/kg.°C) x Exhaust gas rate (kg/hr) x Exhaust heat exchanger effectiveness x (Exhaust gas temperature (°C) - Coolant outlet temperature °C))

It can be assumed that all jacket coolant heat (excluding the radiation losses) is recoverable.

If the recovered heat from the exhaust and jacket is to be used for space heating, the water/glycol coolant is passed through the engine and the exhaust heat exchanger, to the engine radiator where it is cooled by the engine fan before being circulated back to the engine. The warm air coming out of the radiator is ducted to the required space heating location.

The waste heat available for space heating outside the engine room is therefore equal to:

Jacket coolant heat (MJ/hr) + Recoverable exhaust heat (MJ/hr)

The heat available for space heating in the engine room is equal to:

Jacket radiation heat losses(MJ/hr) + Heat losses from generator and radiator fan (MJ/hr)

(Heat losses from the generator and fan equals Engine power output (MJ/hr) times (1 - generator efficiency)).

The engine radiator and radiator fan must be sized such that they can extract all the heat from the engine coolant at full load and deliver warm air for space heating at the required temperature.

Radiator design heat load (MJ/hr)

= Jacket coolant heat at full load (MJ/hr)
+ Recoverable exhaust heat at full load (MJ/hr)

Assuming the coolant is a 50/50 glycol/water mixture (heat capacity = 0.0036 MJ/kg.°C and density = 1.04 kg/l) the coolant temperature drop through the radiator will be given by:

Radiator design coolant temperature drop (°C)

$$= \frac{\text{Radiator design heat load (MJ/hr)}}{\text{Coolant flow rate (l/hr)} \times 0.0038\ \text{(MJ/l.°C)}}$$

Design radiator fan capacity (kg/hr)

$$= \frac{\text{Radiator design heat load (MJ/hr)}}{0.0011\text{(MJ/kg.°C)} \times \text{Design air temperature rise (°C)}}$$

In a typical diesel and heat recovery system, the jacket coolant temperature leaving the engine would be thermostatically controlled below about 80°C, and the air being used for space heating would be heated from about 20°C to about 50°C.

The exhaust heat exchanger would be sized to extract the maximum amount of heat at full load:

Heat exchanger design coolant temperature rise (°C)

$$= \frac{\text{Recoverable exhaust heat at full load (MJ/hr)}}{\text{Coolant flow rate (l/hr)} \times 0.0038\ \text{(MJ/l.°C)}}$$

Heat exchanger design exhaust temperature drop

= Heat exchanger effectiveness x (Engine exhaust temperature at full load (°C) - Coolant outlet temperature at full load (°C))

APPENDIX D

SPECIFICATIONS FOR A 15kW DIESEL GENERATING SET WITH HEAT RECOVERY FOR REMOTE AIRPORT POWER AND GARAGE HEATING

APPENDIX D

SPECIFICATIONS FOR A 15 KW DIESEL GENERATING SET WITH HEAT RECOVERY FOR REMOTE AIRPORT POWER AND GARAGE HEATING

Engine

One only 4-cycle naturally aspirated, liquid cooled diesel engine to operate at 1800 RPM, complete with engine drive coolant pump to operate against a maximum head of 20 feet water. Engine complete with monoblock fuel pump, fuel lift pump, electronic governor, fuel shut down solenoid, jacket coolant temperature detector, oil pressure switch, oil pressure gauge, overspeed switch, replaceable oil filters, combustion air filters, dry type with replaceable elements. Electric cranking starter solenoid and battery leads. AMOT, type B, three way coolant liquid thermostatic control valve. Coolant connections suitable for remote connections to a radiator.

Engine to be sized to drive a 15kW alternator and to have an efficiency of not less than 86% at full load.

The engine shall be capable of developing 20 HP continuously at 1800 RPM under N.T.P. conditions as specified by B.S.S. 649 and of carrying a 10% overload for one hour in every twelve.

Alternator

One only 15kW continuously rated 60°C temperature rise alternator, 4 pole, salient pole type with a Ammortisser winding. 120/240 volt single phase, 60 Hz, 1.0 P.F. complete with directed overhung brushless exciter with rectifier bridge. Exciter is to have a regulation field and an auxiliary field energized via a rectifier bridge from an auxiliary winding acting as a current transformer on the alternator stator winding so as to provide an additive flux mode for the exciter regulator winding. The alternator shall be single bearing type and shall be supplied with a S.A.E. housing and coupling to enable it to be directly coupled to the engine fly wheel housing. Alternator and exciter are to be of the self ventilating type and an adequately sized box is to be supplied over the exciter for all electrical connections and to house the auxiliary excitation equipment. Alternators shall be B.B.C. Canada/Kator or Leroy Somer Canada manufacturer.

Mounting

The diesel engine and alternator are to be mounted on a combined steel base structure designed so that no distortion shall take place between the engine and alternator either during transit or during operation. The whole set on its combined base is to be supported on a minimum of four spring type vibration isolators with elastomer side dampers and with adjustable leveling bolts.

Mounted on the base of the generator set there is to be an oil-tight connection box to which all control wiring on the engine is to be brought and terminated on approved style terminal blocks. Oil type busings shall be provided for wiring leading from the terminal box to other equipment.

Fuel oil connections to the engine lift pump and fuel shutoff solenoid and return line to the day tank shall be connected to the engine by flexible connection lines with woven protective sheeting, and these flexible connection lines shall be sufficiently long so that normal engine movement does not strain the connectors or their SAE type couplings.

A full length stainless steel drip tray manufactured from 304 Stainless Steel turned up at least 1½" all around and rolled at the edge, is to be provided to run under the full length of the alternator set.

Radiator

One engine radiator shall be provided for remote mounting . This radiator shall be supplied with a scroll type blower fan, belt driven by a 220 volt single phase 60 Hz TEFC 55°C temperature rise induction motor of capacity induction run type. The air inlet to the fan shall have provided a mounting frame for a washable type air filter, and air shall be drawn into the radiator from the engine room, blown vertically through the radiator section and discharged either into the garage or to an external duct leading from the top of the radiator. The inlet and filter which are to be provided with the radiator shall be sized such that the inlet velocity does not exceed 1500 FPM.

The radiator element shall be capable of dissipating 65,000 Btu/hr and the fan shall be sized to remove this heat from the radiator with a temperature rise limited to 44°C for a maximum discharge temperature of 65°C with a 21°C inlet temperature. The air pressure drop across the radiator shall not exceed 3" WG and the discharge velocity shall not be greater than 1500 FPM. The outlet plenum of the radiator shall be supplied with two moveable multi-vane louvre type dampers situated 90° apart with a single operating mechanism coupled so that one damper opens as the other closes in the same ratio. The operating mechanism shall be a single Honeywell Electrical Actuator of adequate torque rating 120 volt single phase 60 Hz, the operation of which will be initiated by a thermostat located within the garage.

The cooling circuit of the radiator shall be fitted with a thermostat to control the fan motor so that the fan does not start until the liquid to the radiator reaches 82°C and shuts down when the liquid temperature reaches 77°C.

The main horizontal outlet from the radiator plenum shall be supplied with a flange and matching wall mounting frame so that the radiator can be bolted through the garage wall. The secondary outlet shall be provided with a rectangular throat and flange so that ducting can be connected thereto.

In order to support the radiator it shall be provided with an adequately constructed floor mounting galvanized angle iron mounting frame so constructed that the air outlet to the garage is at least 2.1m above the floor level.

From the secondary air outlet of the radiator a trunking constructed in sections from a minimum of 20 gauge galvanized sheet steel with joining flanges shall be extended upwards through the roof where it is to be terminated with a gooseneck with bird screen. Where the duct passes through the roof, the ducting is to be sealed with a suitable sealing flange.

In order to assure that the air is circulated back from the garage into the engine room, an opening is to be made in the wall between the garage and the engine room and a duct of adequate rectangualr cross-section fabricated from a minimum of 20 gauge galvanized sheet steel is to be carried inside the engine room wall and discharged into the engine room as high as possible. This ducting is to be constructed in such a manner as to minimize conduction of noise from the engine room to the garage. (Hush-a-duct, or equivalent)

Starter

The engine is to be started by a 12 (24) volt DC lead antimony cranking battery of at least 120 ampere hours capacity which is to be supplied with an angle iron floor mounting rack bolted to the floor alongside the generator set in a position to minimize the length of the battery leads but not to interfere with the engine or alternator maintenance facilities.

One wall mounting controlled rectifier battery charger shall be provided with 20 volt single phase 60 Hz input, 12 (24) volt 10 amp DC outlet. The charger is to include voltage and current limit features and is to include a digital DC volt meter and DC ammeter. It shall have M.E.D. indicators for AC power, float and equalize voltage and current limit, and AC manual circuit breaker, soft start, manual initiate, auto terminate equalize timer. Charger shall be Mechron Energy Ltd. Types CR2F-120-012-010B.

Generator Set Controls

One free standing totally enclosed sheet steel engine and alternator control panel with hinged front door (no rear access). Control panel shall include:

- One main 2 pole and neutral air circuit breaker 200 amp capacity with thermal magnetic trips with I.T.L. attachments.

- Two current transformers 150/5 amperes
- HRC form II moulded fuse units with type C form II fuse cartridges
- One set of two wire and neutral bus with incoming cable connectors.

In the front of the panel:

- one AC ammeter 5 ampere range 0-150 ampere scale
- one ammeter transfer switch, line 1, line 2, off.
- one AC volt meter 150 volt range and scale
- one set of volt meter fuses
- one volt meter transfer switch, line 1-N, line 2-N and off
- one engine start push button
- one engine stop push button with lock out ring
- one generator running light
- one Staticraft engine mounting control panel with warning and shutdown for:

  - low oil pressure
  - high coolant temperature
  - overspeed
  - electrical fault
  - low fuel level (warning only no shut down)

- one fuel transfer pump switch manual "off" auto
- one transfer running light
- one frequency and running time meter
- one coolant fan running light

The following distribution circuit shall be provided on a distribution panel mounted behind the front door but not attached thereto but with breaker toggles exposed and accessible.

- Two 240 volt 30 ampere breakers two pole
- Ten - 120 volt 15 ampere breakers single pole

Panel shall be finished inside and out with one coat of priming paint followed by one coat of switchboard grey enamel

All items both inside and on front of the panel shall be identified by lamicord name plates, white letters on black ground.

All internal connections shall be terminated on a common terminal board located at the non-hinged side of the panel. The ends of all wires shall be identified with the smae numbers that appear on the drawings.

Fuel System

One 200 imperial gallon fuel oil day tank shall be provided for mounting in the engine room. The tank shall be of the obround type with mounting feet and with the following headers for:

- vent
- outlet valve and filter
- fuel level switch
- fuel oil pipe
- fuel return pipe
- fuel level gauge

Tanks shall be complete with:

- fuel oil filter and shut off fire valve
- fuel level gauge, fuel level switch or switches to control oil transfer pump motor

One fuel oil transfer pump gear type with integral motor, 20 volt single phase 60 Hz drip proof type shall be provided. The pump capacity shall be nine to ten IGPM and the inlet is to be provided with a shut off valve and an inlet fuel filter.

Exhaust Heat Recovery

One 3" pipe size 304 stainless steel engine exhaust gas heat recovery silencer mounting type 3 for vertical mounting with top side inlet and top vertical outlet shall be used. The heat recovery silencer is to handle 100kg/hr of exhaust gas at 438°C with a gas pressure difference exceeding 5" WG. The silencing level of the unit is to be residential. It is to have 1½" inlet and outlet coolant pipes and to recover a minimum of 20,000 Btu/hr from the above gas with a liquid flow of 9 IGPM of 50/50 glycol/water mixture. The silencer is to be insulated with 2" glass cloth wrapper and with epoxy resin coating. Exhaust pipe to the silencer is to be covered with formed fibreglass half sections wrapped and taped. Water piping between engine jacket, heat recovery silencer and radiator is to be similarly insulated.

All exhaust pipe from the silencer to the outside and from the engine to the silencer should be schedule 5, 3" pipe size or 16 gauge 3" tubing. Joints should be made with Vanstone flanges.

The engine is to be supplied with an adequate supply of ethylene glycol to make up a water mixture of 50/50 glycol water to fill the radiator and engine jacket and the heat recovery silencer in all piping. In order to assure a positive head on the complete cooling system a header tank of at least 2 gallon capacity is to be supplied and is to be mounted above the level of the radiator.

Waste Heat Recovery Control System:

A dual range thermostat with automatic programmable set back shall be provided to control the radiator fan duct dampers and the garage back-up forced air oil furnace. The radiator dampers shall be used as the primary control and shall be actuated by the thermostat to maintain an inside preset temperature of between 8°C and 20°C. When the dampers are fully open and the temperature drops below a temperature between 4°C and 8°C, the thermostat shall activate the back up furnace to maintain the set temperatue. The thermostat shall be 24 volt commercial type, programable for up to 4 temperature changes per day, seven days per week.

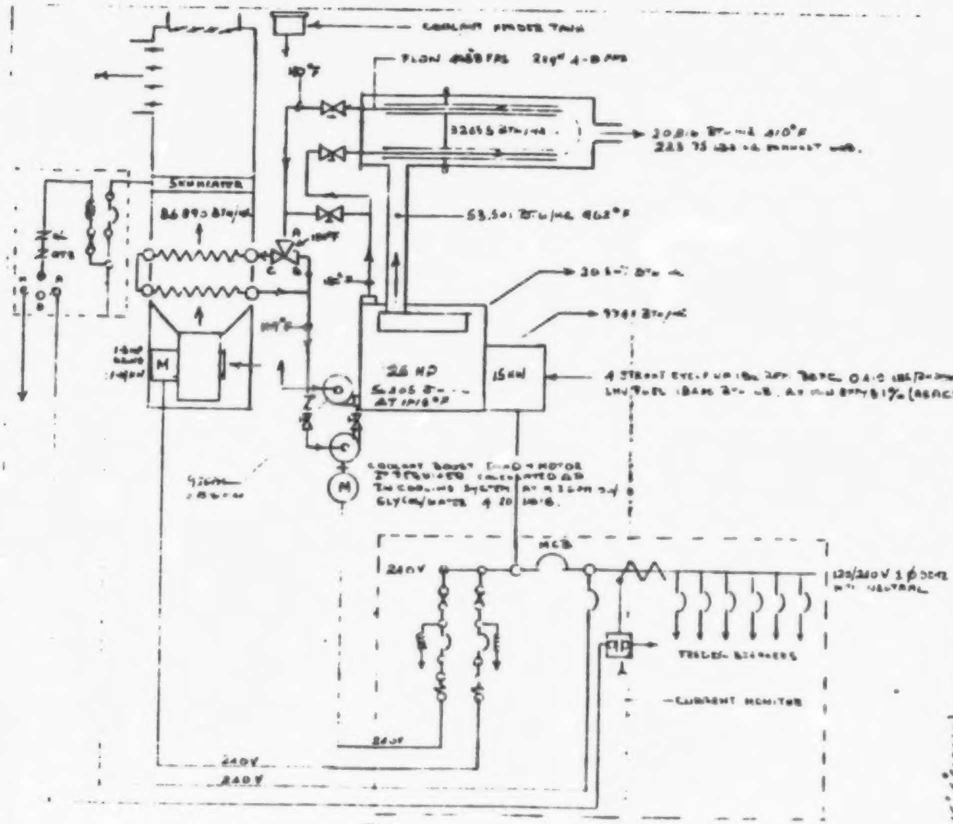
Miscellaneous

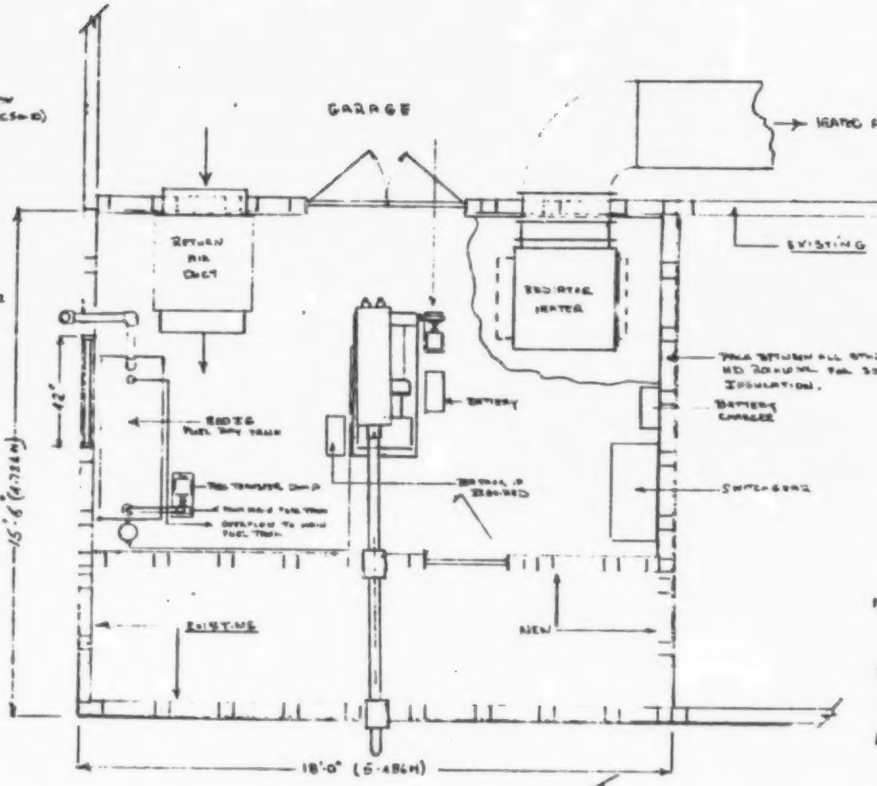
The engine is to be supplied with first filling of lubricating oil, all oil and air filters plus one spare of each type.

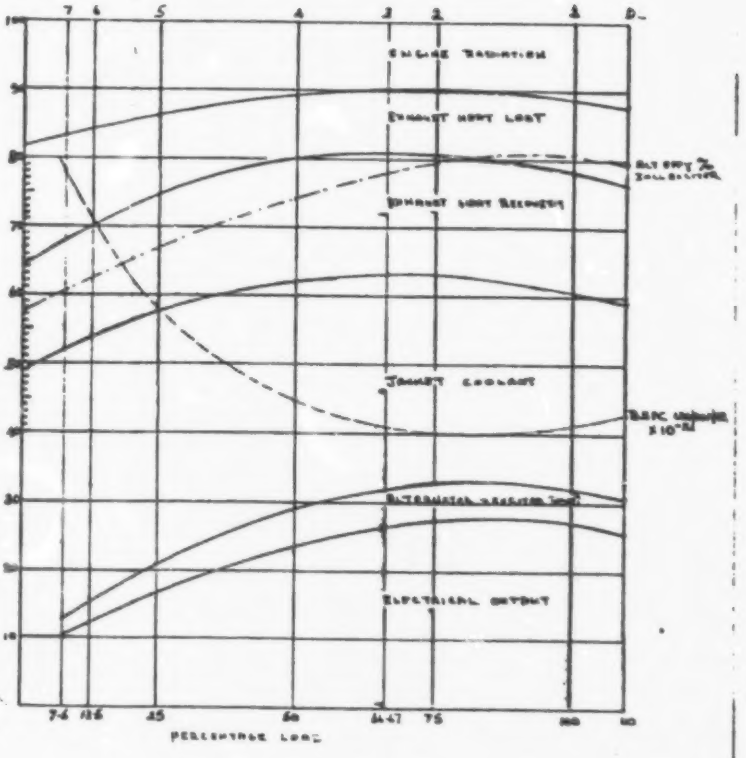
Switch gear is to be supplied with at least two spare fuses of each type supplied.

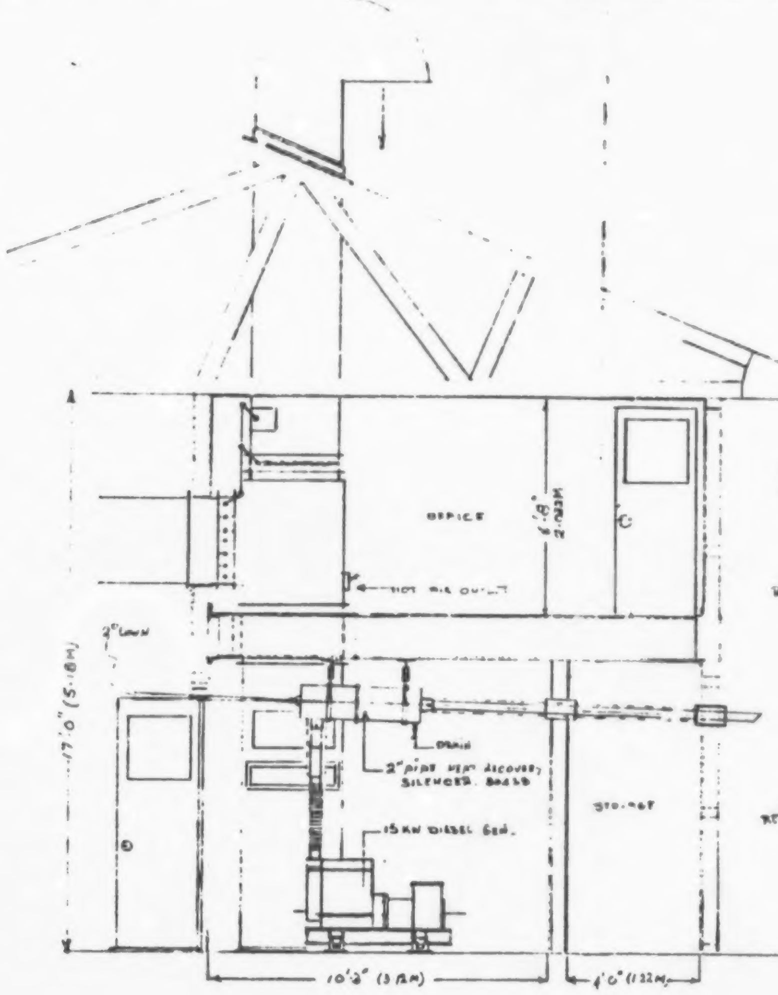
All wiring between the main components of the engine generator set, radiator and control panel is to be carried on cable trays mounted overhead with at least 2.1m clearance from the floor level.

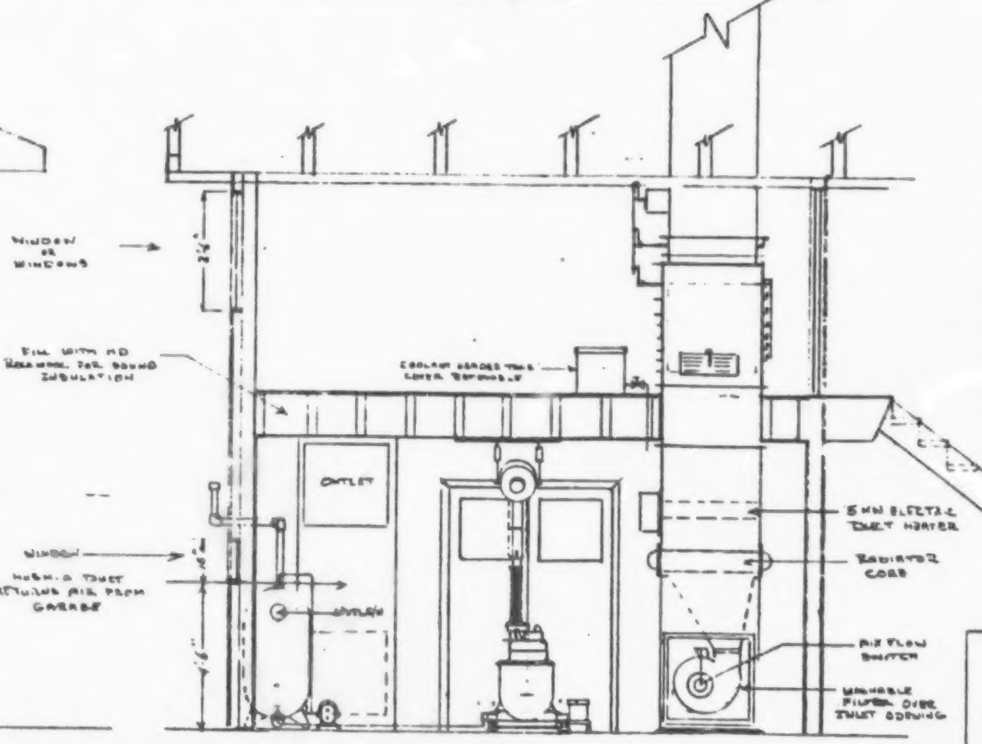
After the engine generator set has been tested in the supplier's factory the cooling system is to be flushed with 50/50 glycol/water mixture before the engine is shipped. In no circumstance is the engine to be tested with water in the cooling system and simply drained.


COOLANT HEADER TANK
FLOW ... 2¼" 4-8 FPS
20,810 BTU/HR 410°F
223.75 LBS/HR EXHAUST ...
RADIATOR
86,893 BTU/HR
53,501 BTU/HR 962°F
26 HP
15KW
4 STROKE CYCLE ... BSFC 0.4·5 LBS/BHP-HR
... AT ... EFFY 81% (ASSESSED)
COOLANT BOOST ... MOTOR
... IN COOLING SYSTEM ... GLYCOL/WATER ...
M
MCB
240V
120/240V 1 Ø 3 CCT WITH NEUTRAL
FEEDER BREAKERS
CURRENT MONITOR
240V


GARAGE
HEATED AIR TO GARAGE
RETURN AIR DUCT
RADIATOR HEATER
EXISTING
BATTERY
BATTERY CHARGER
SWITCHGEAR
FUEL DAY TANK
FUEL TRANSFER PUMP
OVERFLOW TO MAIN FUEL TANK
FILL BETWEEN ALL STUDS WITH ROCKWOOL FOR SOUND INSULATION.
EXISTING
NEW
42"
15'6" (4.724M)
18'0" (5.486M)




OFFICE
HOT AIR OUTLET
2" LAWN
DRAIN
2" PIPE HEAT RECOVERY SILENCER BOARD
15 KW DIESEL GEN.
STORAGE
17'0" (5.18M)
10'2" (3.1M)
4'0" (1.22M)


WINDOW OR WINDOWS
FILL WITH RD ROCKWOOL FOR SOUND INSULATION
COOLANT HEADER TANK COVER REMOVABLE
OUTLET
WINDOW
RETURN AIR FROM GARAGE
5KW ELECTRIC DUCT HEATER
RADIATOR CORE
AIR FLOW SWITCH
WASHABLE FILTER OVER INLET OPENING

MARBEK RESOURCE CONSULTANTS LTD.

SYSTEM #1 SINGLE 15KW CO-GENERATION POWER
MINISTRY OF TRANSPORTATION & COMMUNICATIONS
REMOTE FACILITIES – AIRPORTS.

DESIGNED R.G. BALL.			
DRAWN D.G.S.			
APPROVED	SCALE ⅜" – 1'0"		DWG NO. 3030-RBA-2
DATE 15 MAY 84	SHEET 1	OF 1	

APPENDIX E

SPECIFICATIONS FOR A DUAL 50kW PRIME POWER DIESEL GENERATING SYSTEM WITH HEAT RECOVERY FOR REMOTE AIRPORT POWER AND GARAGE HEATING

APPENDIX E

SPECIFICATIONS FOR A DUAL PRIME POWER 50 KW DIESEL GENERATING SYSTEM WITH HEAT RECOVERY FOR REMOTE AIRPORT POWER AND GARAGE HEATING

General

The following specification details equipment required for a prime power dual diesel electrical generating system which makes full use of heat radiated from the engine jackets and exhaust manifold and from the alternator and exciter to heat the engine room, and at the same time utilizes the heat rejected to the engine coolant and the exhaust gas to provide hot air heating for the service bay of a vehicle garage and maintenance facility forming part of the premises in which the diesel engine room is situated.

Equipment

The external electrical load for which the diesel alternator sets are to be sized will be 50 kW. The power required to drive the electric motor driven fan, associated with a remote radiator, shall be extra to the external load, and the engine continuous horsepower rating shall be in accordance with B.S. 647: 1958, latest amendments or D.I.N. 6270B for generator set applications. Engines ought to be certified by the engine manufacturers' registered performance curves for the engines offered.

The maximum ambient temperature 30°C
Atmospheric pressure 100 KPA
Atmospheric humidity 60%

The engine and alternator and exciter shall be capable of carrying an overload of 10% for 1 hour out of any 12 consecutive hours, beyond a net continuous rating required.

Engines

1. Each of the two engines selected must develop its full load continuous SHP at not more than 10% above the horsepower required for the load. In this case, 93.18 horsepower in order that when supplying the external load the engine is running at approximately 90% of its maximum rated horsepower where it can achieve its best B.S.F.C. and will develop an exhaust gas temperature of not less than 800°F at this load.

2. The engines shall be 4/cycle, direct injection, naturally aspirated and shall operate at 1800 r.p.m. They shall be capable of starting in an ambient of 32°F (0°C) without electrical starting aids such as glow plugs. The engine shall be liquid cooled by a 50/50 mixture of ethylene glycol and water.

Each engine shall be complete with the following:

- one set of removable wet cylinder liners

- one belt driven engine coolant pump capable of operating against a dynamic head of not less than 6m W.G. and of delivering sufficient coolant to limit the full load temperature rise of the coolant through the engine jacket to a maximum of 6°C under the ambient conditions specified.

- one multi-point fuel injection pump with fuel lift pump attached

- one set of fuel injectors, one per cylinder

- one fuel shut off solenoid - enersize to open

- one engine fuel filter with replaceable elements

- one set of high pressure fuel lines between the injection pump and the injectors

- one set of stainless steel fuel lines with stainless steel fittings from the fuel pump to the point on the engine mounting base where the pipe is connected by a flexible pipe connection to the fuel oil supply lines from the day tank.

- one engine panel having mounted thereon one lubricating oil pressure gauge, one engine coolant temperature gauge.

- one lubricating oil pressure switch

- one jacket coolant high temperature switch

- one electrical sensor for overspeed switch (switch to be mounted in the control cabinet)

- one combustion air inlet filter, dry type with replaceable element.

- one engine speed control governor to be of the electronic type with magnetic pick up at the flywheel. The governor itself is to be mounted in the control panel while the electrical actuator controlling the fuel pump drive is mounted on the engine. The remote speed setting rheostat to be mounted on the control panel, Woodward, Barber-Colman or equal.

- one electric engine cranking and starting motor 24 volt DC with gear engaging and starting solenoid. If Bendix type thrust drive is used the solenoid is to be provided as a starter control switch.

- one set of electrical connections of adequate capacity and length to connect the starting batteries to the starter and solenoid.

- one SAE flywheel housing. Flywheel is to be drilled and tapped for use with SAE disk type alternator couplings.

- one set of engine mounting brackets.

The engine is not required to be supplied with an engine thermostatic valve and bypass line. The coolant is to be pumped direct from the jacket outlet via a three-way thermostatic diverter valve to an exhaust heat recovery silencer detailed elsewhere in the specification. A three-way diverter valve is to be supplied and is to be Amot type "B" or equal with an 85° element.

Engines shall be fitted with oil sump heaters and jacket immersion heaters which shall be fed from a circuit on the main distribution panel but which can be switched on only when the engine is stationary and if the ambient temperature in the engine room drops below 0°C.

Alternators

1. The alternators shall be 50 kW 0.8 PF, 62.5 KVA, 120/208 volt, 3 phase, 4 wire, 4 pole, 60 Hz, continuous rated horizontal mounted salient pole synchronous type for operation at 1800 rpm.

2. The alternators shall have drip proof, self ventilated

enclosures and shall have Class "E" insulation. The temperature rise shall not exceed EEMAC.MG-22.4 for Class "B" insulation used in a 50°C (105°F) ambient.

3. The alternator shall be capable of carrying a 10% overload for one hour after 24 hour operation at full load name plate rating of 50 kW.

4. If, in order to limit transient voltage dips due to high and prolonged motor starting currents or other surge loads, the alternator has a higher rating than the 50kW 62.5 KVA specified, the name plate may be marked with this rating but this should be noted on the name plate as a "special" rating and the generator set rating should be noted as SET RATING......kW.

5. The alternators are to be provided with direct connected, overhung AC alternator exciters with full wave rotating bridge rectifier to provide DC to the main alternator field.

6. The exciter is to be self exciting without aid of batteries.

7. The alternator exciter is to be supplied with an auxiliary field supplied through a bridge rectifier from an auxiliary winding on the main field. The main regulating field of the exciter are to operate in an additive flux mode so as to give a sustained short circuit capabilitiy of 300% to the alternator output for 10 seconds at the continuous operating temperature rating.

8. Access to all excitation equipment is to be provided by removable louver ventilated side or end covers over the exciter. The top cover of the exciter may be removable but is to be without openings and is to have its edges

turned and lipped over the exicter enclosure to prevent access to the enclosure by liquid falling on the top of the exciter enclosure.

9. The alternator is to be of a single bearing type and the bearings are to be anti-friction, double shielded with a minimum of 50,000 hours life. A removable grease plug is to be supplied but no grease nipple.

10. The alternator, at the non-bearing end is to be supplied with S.A.E. face and plate type coupling to match the flywheel and S.A.E. housing connection on the engine.

Voltage Regulators

1. Voltage regulators used with the alternators and exciters are to be Basler SR-4A with "fail safe" feature.

2. The regulator is to be housed in the exciter housing or in the generator control panel.

3. All control potentiometers mounted in the exciter housing are to be of the screw driver adjust type. Clockwise rotation to increase their related function. All control potentiometers mounted on the front of the control panel are to have manual adjust knobs with clockwise rotation to increase their related function.

4. Alternator output voltage control potentiometers or tap resistors or auto transformers or chokes are to be capable of adjusting the alternator output voltage -- no load to full load by ±5%.

5. The regulator is to provide steady state regulation from no load to full load at 0.8 power factor lagging within ±2%.

6. The voltage recovery time from load change to steady state shall not exceed 2 seconds.

7. The exciter shall protect against faults due to saturation of the alternator at low frequencies if the generator is running at more than 10% below synchronous RPM.

Generator Combined Base

1. A fabricated steel base shall be provided running the full length of the engine and the alternator. The engine and coupled alternator shall be solidly bolted to this base which shall be of such construction as to prevent movement between the engine and alternator either when in operation or in transit to site.

2. Between the combined base and the concrete mounting provided the generator set manufacturers shall supply a minimum of 4 spring type vibration isolators with elstomer side dampers and with level adjusting bolts and lock nuts, LO-REZ, Korfund-Sampson or equal.

3. Engine flow and return fuel pipes shall be firmly fixed to the engine base as shall coolant flow and return pipes. Between this point and the connection with the incoming piping the manufacturer shall supply wire mesh reinforced flexible connections of suitable lengths terminated with brass fittings at both ends. All pipe fittings shall be SAE, and water pipe fittings shall be standard IPS.

4. An engine drip tray, manufactured from 16 gauge aluminum with a 1 inch loop all around and with rolled edges shall be supplied to fit between the mounting rails of the base for the full length of the generator set.

5. On the combined base an oil type electrical connection box shall be mounted to which all electrical wiring on the engine shall be brought through oil type seals. Connections inside the box shall be made to terminal blocks with separate brass connection bars and a minimum number 8 screw size. All connections shall be made with compression type eyelet or spade cable connectors, and all terminals shall be identified in accordance with the drawings. All wiring terminations at the terminal blocks shall be identified by expandable elastomer sleeves with indelibly marked numbers.

6. All control wires on the engine shall be a minimum of number 12 stranded extra flexible flame seal cable and all wiring shall be bundled in harnesses and protected with flexible spiral PVC sleeving.

7. Engine cranking motor cables from the battery shall be stranded type of adequate size to limit the voltage drop across the cables with full cranking amps to 1.0 volts DC at 0°C. The negative cable shall be connected direct to a grounding stud on the engine casting, and the positive cable shall be connected directly to the starting solenoid. Cables shall be clamped to the engine mounting base with a steel clamp bolted to the base from which the cables are fully insulated with hard fibre insulation blocks. Cables shall be of sufficient length to allow for mounting of the batteries on either side of the engine.

Engine Starting Battery System

1. The engine shall be started by 24 volt DC cranking motors as specified above.

2. The starting batteries are to be of the sealed type with hard rubber casings. The battery is to have sufficient cold cranking ampere capacity to be able to crank the engine for a continuous period of 60 seconds at 10°C (50°F) without the voltage dropping to less than 75% of the nominal voltage during this cranking period. The batteries shall be Excide "hycap CSD", Presto lite, or Willard.

3. Floor mounting battery racks with support legs and floor mounting lugs shall be supplied, the steel is to be suitably primed and painted with acid resistant paint. A wood, or fibreglass battery cover or covers should be provided to fit over the batteries to prevent short circuit of battery terminals by accident. The batteries may be located on either side of the engine close enough to minimize but not so close that they interfere with normal maintenance functions.

4. A complete set of battery accessories is to be provided, including hydrometer with wall mounting bracket.

5. Battery charger shall be of the control rectifier type for operation from 120 volt single phased 60 Hz and with a nominal output of 24 volt DC at 10 amperes. The charger is to be totally sheet steel enclosed, self ventilated wall mounting and is to include voltage limit and current limit features. It is to include:

    - AC input circuit breaker
    - DC output circuit breaker
    - Digital DC volt meter and ammeter
    - LED indicators for AC power, float or equalized charge mode
    - Soft start
    - Auto initiate, auto terminate equalizer timing

programmer
- Low battery voltage alarm

Charger shall be Mechron energy limited type CR2F--120-24-010B

Engine Cooling Radiator

1. Engine cooling radiators shall be remote from the engines and shall be mounted in the engine room and against the wall separating the engine room and the garage in such a manner that the cooling air for the radiators is drawn from the engine room and discharged from the radiators into the garage as heating air.

2. Each radiator assembly shall consist of an angle iron self supporting, floor mounting structure with galvanized sheet steel siding. The air is to be drawn in from the bottom side through a removable and washable air filter, pass through a scroll case type electric motor driven ventilation blower which discharges to the underside of a horizontally mounted radiator core. After leaving the radiator core the air is to pass through an electrical heating element specified later and discharged through a louvered and adjustable damper mounted on the opposite side of the assembly from the inlet filter, but above the radiator and heater, and discharged into the garage. The alternative path for the discharge, heated air, will be directly upwards through a second adjustable louvered damper, through a throat with connection to a discharge ducting leading up through the roof of the engine room and terminated by a gooseneck and bird screen. Where this duct passes through the roof it shall be fitted with a sealing ring.

   Ducts sections shall be not more than 4 feet long between the joints and shall be constructed from not less than 22 gauge (0.0336 IN) galvanized sheet steel. All duct section walls shall be braced to give strength and to prevent distortion due to changing temperature or pressure conditions.

3. Joints on longitudinal sections of ducts shall be Pittsburgh lock, or groove type. Transverse joints, except those at the radiator outlet and at the terminal gooseneck, shall be pocket or slip type on two opposite sides with drive slips on the other two sides. Joints at the radiator and at the terminal gooseneck section shall be fabricated, galvanized iron flanges 1" x 1/8" and shall be connected by "U" slip pieces with ¼" locking bolts and nuts through each end of the slips.

4. Where the trunking leaves the radiator to pass into the garage it shall be 3" long and shall be terminated with a flange which bolts to one side of the louver damper. From the other side of the louvered damper a short section of galvanized sheet steel trunking shall be provided to project into the garage.

5. A two-part wall mounting thimble, the one part slip fitting into the other, with matching flanges shall be provided to carry the ducting through the wall. The flanges shall be a minimum of 2" wide all around. The clearance of the thimble around the duct shall not exceed 1/16 of an inch.

6. The two louvered dampers shall have their operating linkages coupled together so that as one opens the other closes in the same proportion. The dampers shall be operated by an electric motor driven actuator, 120 volts, single phased, 60 Hz with limit stops and switches (Honeywell or equal). The motor operator is to be

controlled by a thermostatic switch mounted in the garage and by a thermostatic switch mounted in the outlet duct immediately above the radiator to assure that the air is discharged into the garage only when it reaches a preset minimum temperature.

7. A 10 kW resistance type 208 volt 3 phase 60 cycle should be mounted horizontally at least one foot above the radiator core, between the radiator and the outlet dampers;

   This resistance heater is energized as a dummy load on the radiator ducting in the event that the electrical load on the generator drops below 10kW.

   The control and connection box of this unit shall be mounted external to the radiator duct structure and shall include switching contactor, over temperature protection, external off-auto switch. The contactor control circuit shall be connected in series with a control relay energized by the air flow switch so that electrical heater cannot be switched on unless the air is flowing.

8. a) The radiator is to be sized so that it will remove heat dissipated to the engine coolant from the engine and from the exhaust heat recovery silencer when operating under the 110% load condition in a maximum ambient temperature of 30°C.

   b) The coolant will be a 50/50 mixture of ethylene glycol and water having a specific gravity of 1.045 and a specific heat of 0.861 Btu/lb/°F. The flow rate will be that developed by the engine driven coolant circulating pump and the maximum dynamic head loss through the radiator and piping and the heat recovery silencer must be considered in relationship to the engine manufacturer's recommendations regarding this pump.

c) The temperature of the coolant to the radiator under the 110% load condition will be 88°C and the coolant must be returned to the engine at not more than 78°C (calculation based on heat balance for a naturally aspirated engine).

d) The maximum velocity of air leaving the radiator ducting to the engine room, or a discharge to the outside must not exceed 5 m/s and the maximum air temperature out of the radiator must not exceed 65°C.

e) The radiator and radiator fan should be sized to remove a maximum of 328 MJ/hr (311,000 Btu/hr) from the engine coolant and deliver air to the garage at between 20°C and 50°C.

f) A balance tank having a minimum capacity of two imperial gallons complete with site glass, fill port with 7 PSI radiator cap and a ½" outlet half coupling and wall mounting brackets shall be supplied for mounting above radiator level.

9. The radiator fan shall be of the cage type with scroll case and shall be belt driven at a suitable speed by a 220 volt three phase 60 Hz squirrel cage induction motor, totally enclosed fan cooled, or totally enclosed air-over. The fan horsepower shall be determined by the total pressure drop across the inlet air filter and radiator and the pressure drop through either damper and the discharge air duct.

The motor shall be connected by a 3 phase maotor starter of suitable size protected by HRC form 2 fuses in moulded fuse units connected directly to the alternator circuit breaker. The starter shall start as soon as the alternator voltage is sufficiently high to close the starter contactor.

10. An airflow switch of the deflective panel type shall be mounted immediately behind the inlet air filter and shall be connected to the engine protective system on the control panel to shut down the engine and give warning should the motor fail or the drive belt break.

Engine Room Inlet Ducting

1. The combustion air for the engine, and the cooling air for the radiator will be drawn from the garage during the heating season and for this purpose a duct will be mounted in the engine room on the wall between the engine room and the garage.

   The inlet of the duct leading from the garage is to be 3 feet from the floor of the garage and the outlet from the duct, in the engine room, should be just below the roof level. In order to minimize noise transmission from the engine room to the garage the duct shall be of the sound attenuating type - Hush-a-Duct or equal. The duct should be of such a size that the pressure drop with full air flow should not exceed 0.5" WG.

Engine Room Inlet Damper

1. During the summer months when the outlet air from the radiator is discharged up through the roof there could be a negative pressure in the garage when the doors are closed and this will reduce the cooling air flow to the

radiator.

2. In order to overcome the negative pressure problem outlined in (1) a manually operated close ceiling louvered type damper is to be fitted in a convenient outer wall of the engine room. This damper sould be fitted with a bird screen and internal washable inlet filter. The damper can be opened manually to the desired degree and locked in that position during the summer months.

Engine and Alternator Control Panel and Distribution Switch Gear

General:

1. The switch gear, control and distribution panel shall be totally sheet steel enclosed, free standing and shall be fabricated from a minimum of 12 gauge (0.1046 manufacturer's standard) sheet steel, break formed with reinforcing break formed angles where necessary. The back panels shall be removable but not hinged as rear access is not required. Front doors should have a minimum of 3/4" lip edges which should overlap a minimum of 3/4" deep door frames. Front front doors in all sections shall be hinged on the same side, and all doors should be provided with plated handles and three point catches. The door handles should be provided with barrel type locks having a common key.

   Inside of the panels should be thoroughly degreased and phosphatized, and finished with a flat white enamel paint. The exterior of the panels should be degreased, phosphatized, primed and finished with high gloss switchboard grey enamel.

2. All copper bus connections in the switchboard should be covered with shrink on PVC covering and all bus joints shall be held together with plated steel bolts with plated nuts and Belleville washers.

3. Bus support shall be provided at all points where the bus passes between cubicles and shall be of the steel frame type with split insulation materials of an acceptable thickness and type. The bus shall be braced to withstand stresses created by any short circuit.

4. All control wiring inside the panel shall be a minimum of number 12 solid copper flame seal.

5. All wiring through instruments and control panels mounted on the front panel should be a minimum of number 12 stranded extra flexible flame seal and these cables shall be terminated on the control panel by rigidly mounted terminal boards having a minimum of number 8 screw and keeper for each end of the connection bar. Individual connections shall be separated by dividers at least 1/8" longer than the bars at each end and ¼" higher. Wiring between the terminal boards and the front of the control panel shall be bundled in harnesses and supplied with at least one stirrup with spring mount.

6. Terminal boards for connection of incoming control wiring shall be of the type described in (5) above and all terminals shall be identified with numbers shown on the drawings. The ends of all wires connecting to the terminal boards shall be identified with expandable elastomer sleeves with indelible markings.

7. All instruments and switches mounted on the front panels shall be identified with Lamicord name plates, black

letters on a white ground. Lettering to be a minimum of ¼".

8. All equipment mounted inside the panel is to be identified with 3/8" wide Dymo stick-on strips, white letters on red ground.

Alternator Panels:

9. Circuit breakers are to be provided inside the alternator panels on a substructure with their operating handles projecting through a shielded opening in the front door. Circuit breakers shall be 1-3 pole manually operated moulded case air type, 600 volt class, 200 amp rating with thermo magnetic trips with ITL attachments and with 24 volt DC shunt trip. Breakers are to be supplied with compression type cable connectors for incoming cables. Three current transformers, ring type, 200/5 amperes are to be mounted on the bus. One three pole magnetic motor starter with overload trips 208 volt operating coil (cooling fan motor starter), three HRC moulded fuse holders with form C HRC fuses (fuses to be suitable to protect the fan motor are to be provided), one combined over and under voltage monitor, one main control relay, and one engine start relay are to be mounted inside the cubicle.

   The following shall be mounted on the front of the alternator control panels:

   - one 4" rectangular semi flushed type phenolic case ammeter, range 5 amperes, scale 0 to 250 volts, AC 60 Hz, 2% class.

   - one three point and off ammeter switch

- one 4" rectangular semi flushed phenolic case volt meter, range and scale 0 to 250 volts AC 60 Hz, 2% class
- one volt meter transfer switch 3 point and off
- one engine start push button
- one engine run pilot light - red
- one engine control switch - run and off.

The engine safety annunciation system shall include:

- Alarm and Shutdown:
  - low lubricating oil pressure
  - high jacket coolant temperature
  - over speed
  - cooling fan shutdown
  - electrical fault
- Alarm only without shutdown:
  - low fuel oil level

Electrical fault shall include over voltage, under voltage, reverse power and breaker trip.

Annunciators shall be 20 volt DC actuated and shall be of the latching relay electromechanical type with visible indicator on the reset push button. Mechron Energy Limited type AN or equal.

One alarm flashing light (white), one alarm buzzer with high note of sufficient intensity and power to be heard above the engine room noise, and one alarm silence push button shall be provided. Silencing the alarm shall leave the light flashing until the fault annunciation involved can be reset after the fault is cleared.

Transfer Switch and Panel:

10. a) The transfer switch shall be a 3 pole 200 ampere unit employing 2 interlocked mode case circuit breakers as switching units.

b) The switch shall have normal and emergency supply connections, normal supply voltage sensing relay, engine start contacts to close when normal supply fails, neutral bar, program switch to select which set is normal and which is in the emergency mode, load on normal pilot light, load on emergency pilot light, a manual return button (when pressed this disconnects the energy supply and allows reconnection of the normal supply immediately if it is available), frequency sensing emergency relay, and frequency sensing normal relay.

Distribution Panel:

11. This panel shall be of the same height and depth as the engine and alternator control panels and the emergency transfer panels and shall contain the following three pole circuit breakers with operating handles accessible from the front of the panel.

- one 200 ampere, 3 pole, 600 volt class moulded case air circuit breaker with thermal magnetic trips
- one insulated neutral bar
- six spaces for 100 ampere 600 volt class 3 pole moulded case air circuit breakers. Supply only 3 breakers

installed.

- six spaces for kWh meters with thermal load demand analogue indication of kW. Supply only 3 meters.

  necessary current transformers for use with the above kWh demand meters shall be supplied, with all necessary bus connections in the three spaces, clamps for current transformers, and wiring terminal blocks for installation of future feeder breakers and kWh/demand meters. Holes in the front of the panel for the kWh demand meters are to be closed with removable plates.

- one current monitor to be supplied on one phase of the bus immediately following the main 200 ampere circuit breaker. This is to be supplied along with a suitable control relay 120 volt single phased 60 cycles with protective HRC fuse in a moulded fuse unit. This monitor will be used to switch on a 10 kW 3 phased dummy load in the radiator ducting in the event that the load on the generator drops below a preset level of 10 kW (35 amperes).

Exhaust Heat Recovery Silencer (HRS)

1. The exhaust heat recovery silencer shall be 4" pipe size and shall be an extended surface water tube type made entirely from 304 stainless steel. It shall be vertically mounted on support legs and the exhaust inlet shall be horizontal at the side and top of the unit with exhaust outlet directly from the top centre of the unit. Exhaust pipe terminations shall be steel plate flanges to ANSI 125 drilling sizes. Water inlet and outlet shall be 1½" IPS. The heat recovery sections shall consist of longitudinally finned stainless steel tubes with surrounding shroud tubes for maximum efficiency.

The unit shall provide maximum economical heat recovery at full engine load while not imposing a pressure on the exhaust system in excess of the engine manufacturer's recommendation.

2. HRS unit is to provide residential level silencing.

3. The top chamber of the HRS unit is to be removable for inspection and with the top removed the whole tube bundle where the tubes and shrouds are, is to be removable.

4. The unit shall have low liquid content to ensure fast warmup and the wet weight should not exceed the dry weight by more than 10%.

5. The HRS unit shall be fabricated in accordance with ASME code section VIII (dif I) for hot water. The maximum water pressure is not to exceed 75 PSIG.

6. The unit shall be assembled with liquid shut off valves on the inlet and outlet and with a liquid drain valve at the lowest point. Interconnecting pipe between the inlet and outlet shall be provided with a by-pass/liquid flow control valve at the centre.

7. It shall be possible to operate the unit for a prolonged period dry at exhaust temperatures not in excess of 425°C.

8. When installed, the HRS shall be insulated with a minimum of 2" thick fibreglass solid insulation with fibreglass cloth backing wrapped with fibreglass cloth and coated with epoxy resin.

9. All exhaust piping from the engine to the HRS and from

the HRS to the outdoors shall be schedule 5 304 5" stainless steel pipe with stainless steel flexible connectors as required by the installation. Flanges shall be Vanstone type.

10. All exhaust piping and coolant pipes shall be insulated with moulded fibreglass piping insulation overtaped and painted.

Waste Heat Recovery Control System

A dual range thermostat with automatic programable set back shall be provided to control the radiator fan duct dampers and the garage back-up forced air oil furnace. The radiator dampers shall be used as the primary control and shall be actuated by the thermostat to maintain an inside present temperature of between 8°C and 20°C. When the dampers are fully open and the temperature drops below a preset temperature between 4°C and 8°C, the thermostat shall activate the backup furnace to maintain the set temperature. The thermostat shall be 24 volt commercial type, programable for up to 4 temperature changes per day, seven days per week.

Spares

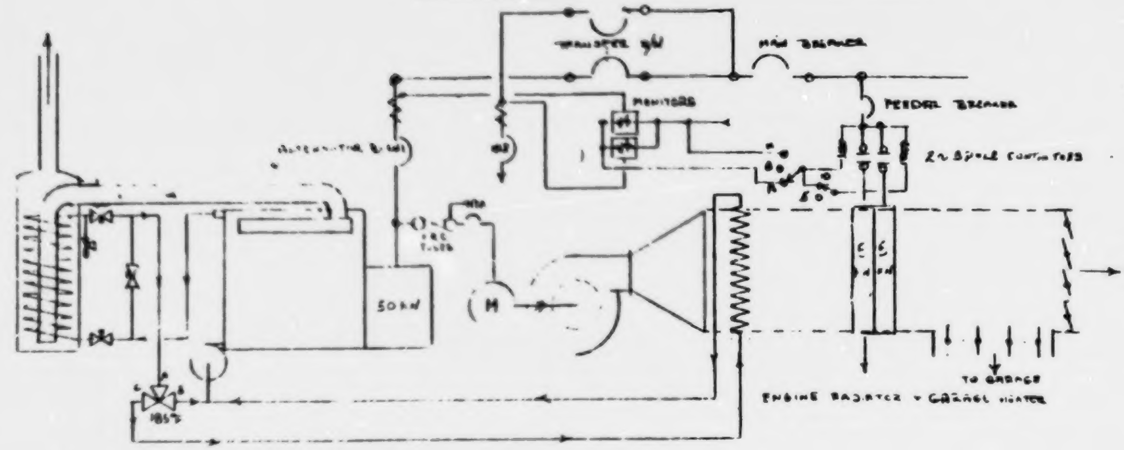
The following minimum spares shall be supplied with the installation:

- 6 fuel oil filter replaceable elements
- 3 engine combustion air filter replaceable elements
- 6 engine lubricating oil filter replaceable elements
- 1 spare lamp for each pilot light supplied with equipment
- 6 spare fuses for each size and type supplied with the equipment
- 2 spare engine valve cover gaskets

- sufficient antifreeze ethylene glycol to fill the engine cooling and heat recovery systems.

Shipping Note

After the engine generator set has been tested in the manufacturer's facilities it is to be drained and flushed with 50/50 ethylene glycol mixture. It is on no account to be shipped with water or water residue in the jacket during the cold months of the year.


TRANSFER SW
MAIN BREAKER
MONITORS
FEEDER BREAKER
ALTERNATOR BLOWER
2 x 3 POLE CONTACTORS
50 KW
M
185°F
TO OUTSIDE
TO GARAGE
ENGINE RADIATOR + GARAGE HEATER

T1	200	195	190	185	180 TM	
920	1.0	1.008	1.015	1.022	1.030	
850	1.0	1.015	1.025	1.050	1.065	MEAN
700	1.0	1.025	1.040	1.065	1.080	LIQUID
380	1.0	1.050	1.065	1.080	1.100	TEMPERATURE (MLT)
280	1.0	–	–	–	–	CORR° FACTOR

STEP 1. WITH 'W' WEIGHT EXHAUST GAS IN LBS/HR READ UP TO APPLICABLE T1 LINE, READ HORIZONTALLY Q = BTU/HR

STEP 2. CALCULATE $\frac{Q\ (BTU/HR)}{LBS/HR\ LIQUID}$ = ΔT LIQUID

STEP 3. CALCULATE MLT = $\frac{2 \times INLET T + \Delta T\ LIQUID}{2}$

STEP 4. MULTIPLY Q × MLT CORR° FACTOR = FINAL Q (BTU/HR)

STEP 5 $\frac{FINAL\ Q\ (BTU/HR)}{'W' \times Sh\ (0.265)}$ = ΔT EXHAUST GAS

STEP 6. INITIAL T1 − ΔT EX GAS = FINAL T2.

NOTE. IF LIQUID OTHER THAN WATER MULTIPLY WEIGHT OF LIQUID BY Sg. AND Sh.

EXAMPLE: EXHAUST FLOW 440 CFM @ 920°F MAX. COOLANT FLOW 33 IGPM 50/50 GLYCOL WATER Sg 1.045 Sh 0.861, COOLANT CONTROLLED TEMP 185°F

CONVERT CFM TO LBS/HR $440 \times \frac{(70+460)}{(920+460)} \times 0.075 \times 60$ = 820 LBS/HR

STEP 1. WITH 'W' = 820, Q = 1.1×10^6

STEP 2. $\frac{1.1 \times 10^6}{33 \times 10 \times 1.045 \times 0.86 \times 60}$ = 6.13°F ΔT

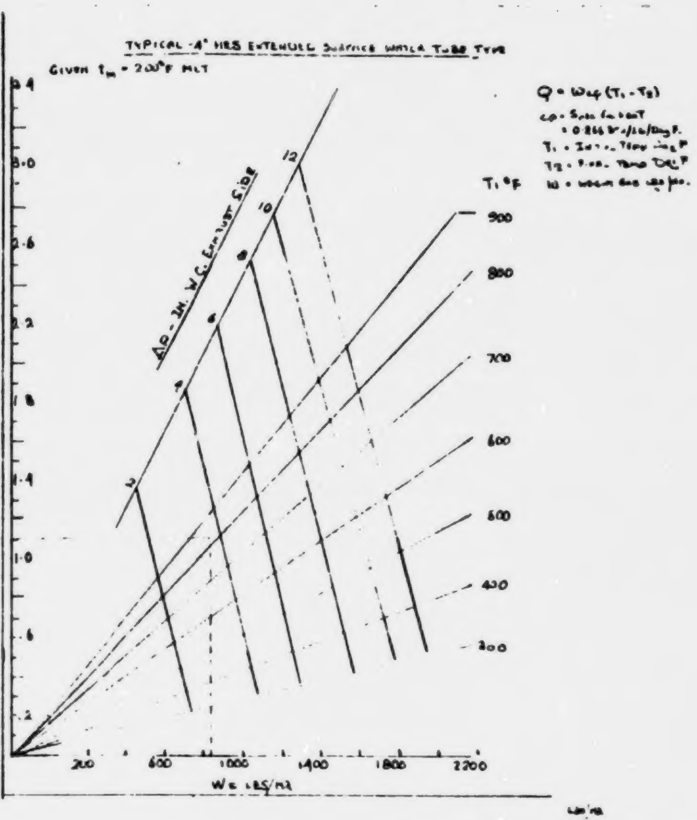
STEP 3. $\frac{2 \times 185°F + 6.13°F}{2}$ = 188°F MLT

STEP 4. $1.1 \times 10^6 \times 1.02$ = 1.122×10^6

STEP 5. $\frac{1.122 \times 10^6}{820 \times 0.265}$ = 516.3°F ΔT

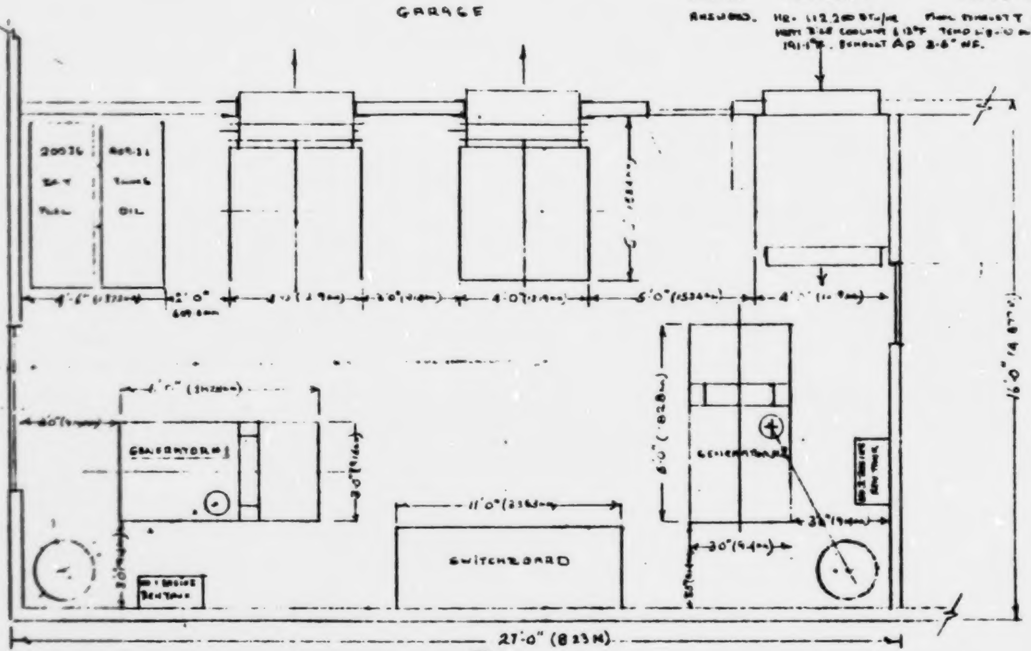
STEP 6. 920°F − 516.3°F = 403.7°F = T2

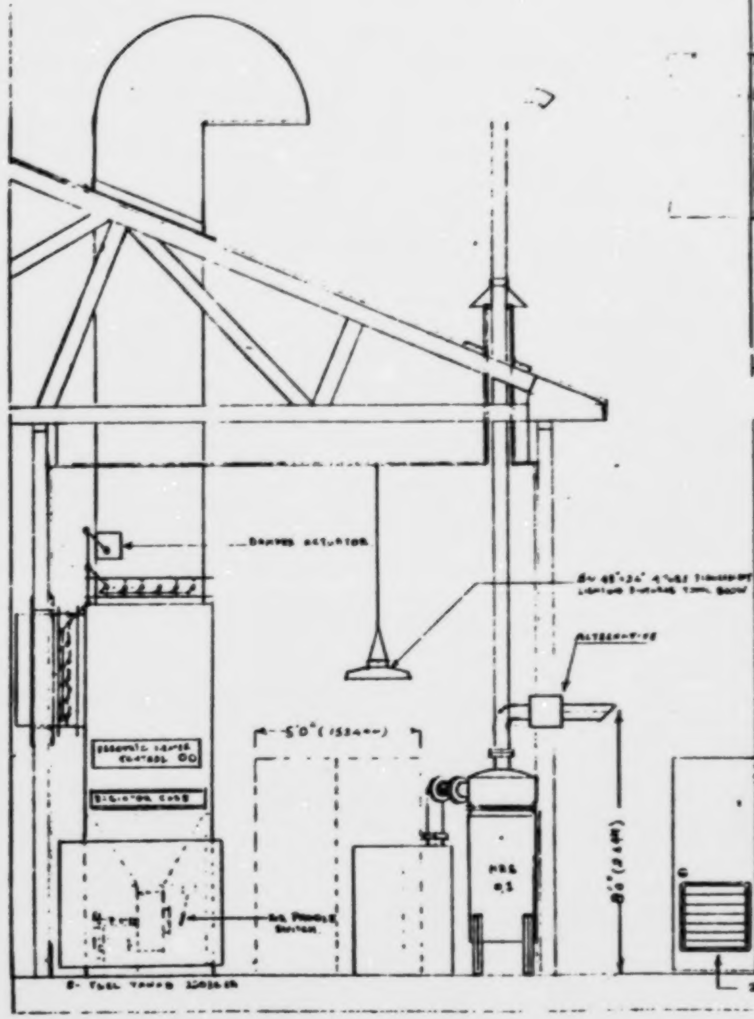
ANSWERS. HR = 112,200 BTU/HR FINAL EXHAUST T = 403.7°F HEAT RISE COOLANT 6.13°F TEMP LIQUID OUT OF HRS 191.1°F. EXHAUST ΔP 3.6" WC.

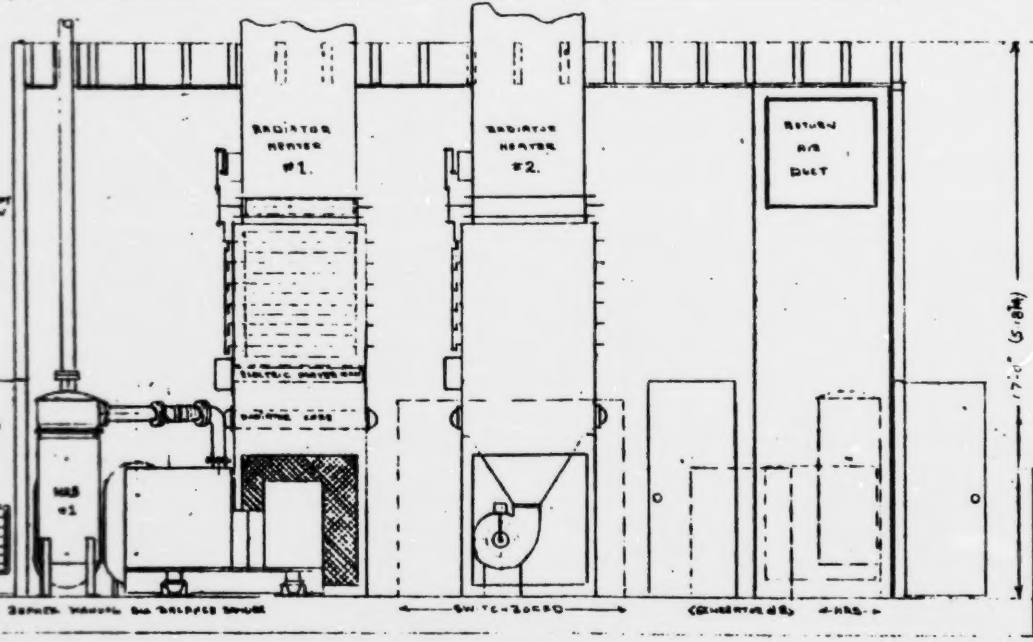


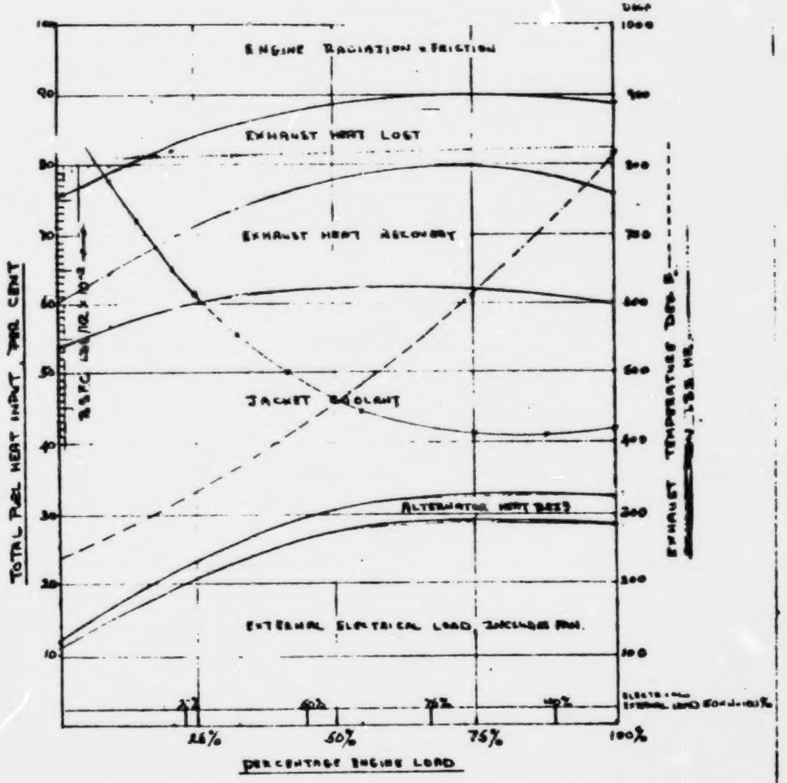
1. UNLESS AIR IS FLOWING PAST AIR PADDLE SWITCH WITHIN 15-20 SECONDS OF ENGINE START PADDLE SWITCH WILL REMAIN CLOSED AND ENGINE WILL SHUT DOWN WITH FAULT ANNUNCIATION.

2. IF THE LOAD ON THE RUNNING GENERATOR SET FALLS BELOW A PRESET LEVEL THE CURRENT MONITOR ON THAT SET WILL INITIATE SWITCHING ON A PRESELECTED 5 OR 10 KW NON INDUCTIVE HEAT LOAD IN THE OUTGOING DUCT FROM THE RADIATOR. THE OUTPUT FROM THIS HEATER WILL SUPPLEMENT THE HEAT TO THE ENGINE ROOM. AT THE SAME TIME, THE INCREASED LOAD ON THE ENGINE WILL INCREASE THE HEAT TO THE COOLANT AND TO THE HRS SO THAT THE HEAT TO THE RADIATOR WILL ALSO INCREASE. ALL OF THIS HEAT WILL BE AVAILABLE FOR HEATING THE GARAGE. BECAUSE OF ENGINE LOAD INCREASE THERE WILL ALSO BE AN INCREASE IN HEAT RADIATION FROM THE ENGINE JACKET & THE ALTERNATOR WHICH WILL INCREASE HEATING TO THE ENGINE ROOM.


GARAGE
200 IG SET FUEL
45 IG LUBE OIL
GENERATOR #1
GENERATOR #2
SWITCHBOARD
11'0" (3353mm)
5'0" (1524mm)
4'0"
3'0"
6'0"
16'0" (4.87M)
27'0" (8.23M)


DAMPER ACTUATOR
ALTERNATOR
5'0" (1524mm)
8'0" (2.4M)
HRS #2
FUEL TANKS


RADIATOR HEATER #1
RADIATOR HEATER #2
RETURN AIR DUCT
HRS #1
17'0" (5.18M)
SWITCHBOARD
GENERATORS



MARBEK RESOURCE CONSULTANTS LTD.

DUAL 50 KW. CO-GENERATION POWER PLANT
MINISTRY OF TRANSPORTATION & COMMUNICATIONS
REMOTE FACILITIES — AIRPORTS.

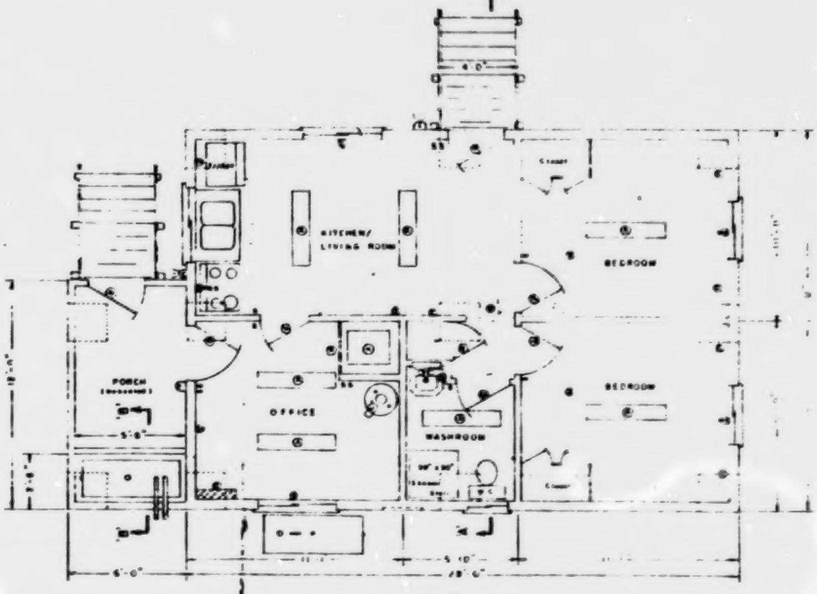
3	ADDED HRS EXAMPLE	9/1/84	
2	ADDED EXTERNAL LOAD SCALE	9/6/84	RZ
1	ADDED BSFC CURVE	9/5/84	RZ

DESIGNED BY R.C. BELL.
DRAWN BY R.C.B.
APPROVED
DATE 5 MAY 84
SCALE 3/8"—1'0"
SHEET 1 OF 1
DWG NO. 3030-RBA-1

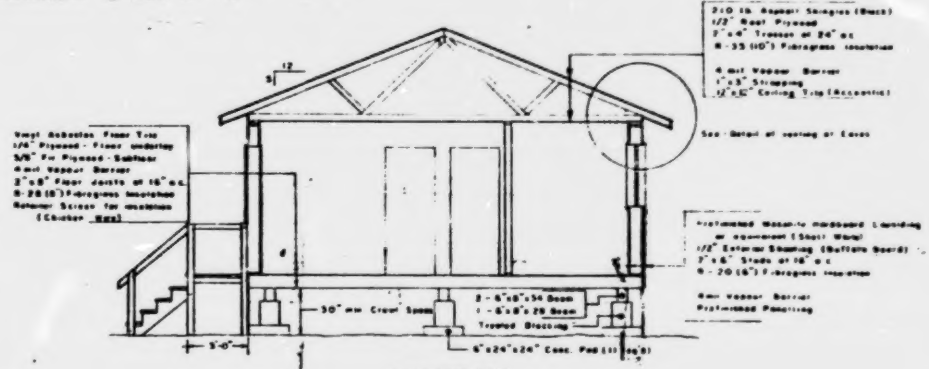
APPENDIX F

LANSDOWNE HOUSE
AIRPORT OFFICE/ACCOMODATION BUILDING:
CURRENT MTC LAYOUT AND SPECIFICATIONS

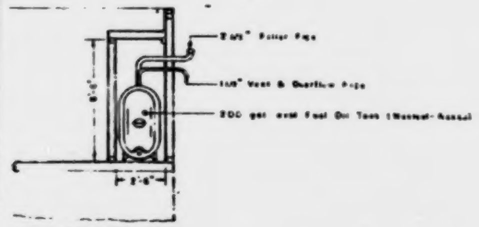
MINISTRY OF TRANSPORTATION AND COMMUNICATIONS ONTARIO   PR-D-724   74-08


KITCHEN/
LIVING ROOM
BEDROOM
BEDROOM
OFFICE
WASHROOM
PORCH
(enclosed)
Closet
Closet
4'-0"
5'-6"
6'-0"
5'-10"
28'-0"

PLAN LAYOUT

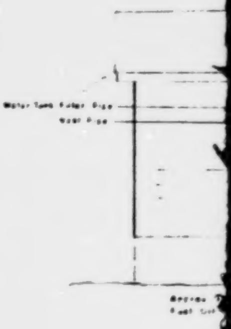

210 lb. Asphalt Shingles (Black)
1/2" Roof Plywood
2"x4" Trusses at 24" o.c.
R-35 (10") Fibreglass Insulation
4 mil Vapour Barrier
1"x3" Strapping
12"x12" Ceiling Tile (Acoustic)
See Detail of venting at Eaves
Vinyl Asbestos Floor Tile
1/4" Plywood - Floor underlay
5/8" Fir Plywood - Subfloor
4 mil Vapour Barrier
2"x8" Floor Joists at 16" o.c.
R-20 (6") Fibreglass Insulation
Retainer Screen for insulation
(Chicken Wire)
Prefinished Masonite Hardboard Lapsiding
or equivalent (Shell Wood)
1/2" Exterior Sheathing (Buffalo Board)
2"x6" Studs at 16" o.c.
R-20 (6") Fibreglass Insulation
4 mil Vapour Barrier
Prefinished Panelling
30" min. Crawl Space
2 - 6"x8"x34 Beam
1 - 6"x8"x28 Beam
Treated Blocking
6"x24"x24" Conc. Pad (11 req'd)
3'-0"
12
5

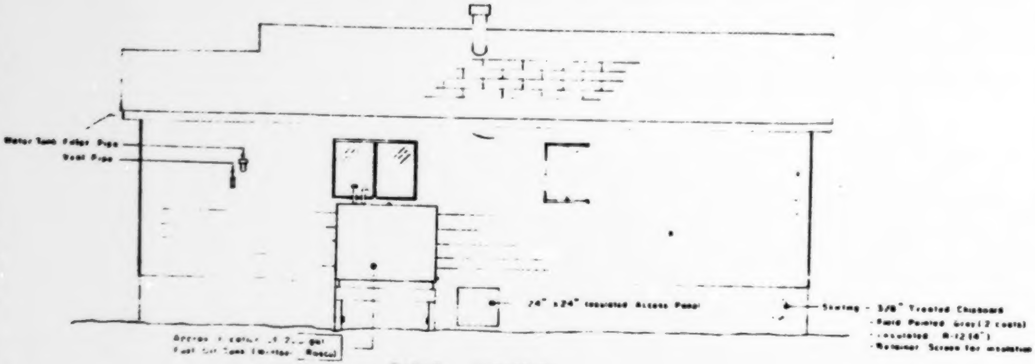
SECTION 'A'-'A'


2 1/2" Filler Pipe
1 1/2" Vent & Overflow Pipe
200 gal. oval Fuel Oil Tank (Natural-Assoc.)
6'-0"
2'-6"

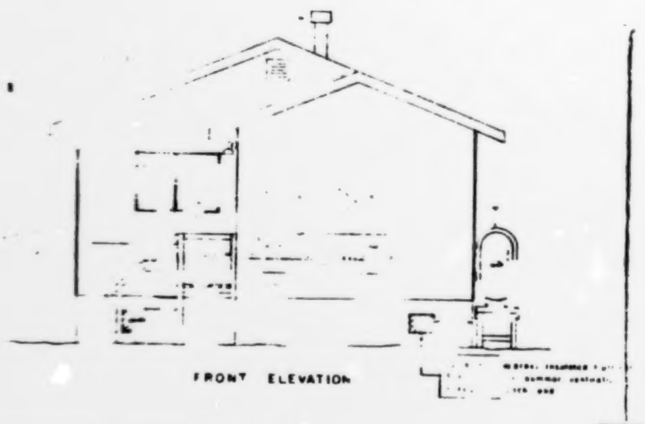
WATER STORAGE TANK

SECTION 'B'-'B'

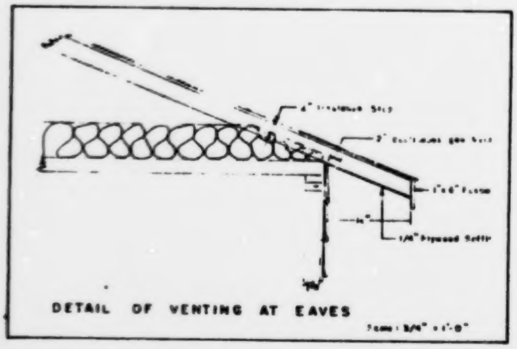

Water Tank Filler Pipe
Vent Pipe


Water Tank Fuller Pipe
Vent Pipe
24" x 24" Insulated Access Panel
Skirting - 3/8" Treated Chipboard
- Paint Painted Grey (2 coats)
- Insulated R-12 (4")
- Retainer Screen for insulation
Approx. Fuel Oil Tank

RIGHT ELEVATION



FRONT ELEVATION


4" Insulation Stop
2" Continuous gap vent
1"x6" Fascia
16"
1/4" Plywood Soffit

DETAIL OF VENTING AT EAVES

Scale: 3/4" = 1'-0"

PORCH CONSTRUCTION :

Outside Walls –
- 3/8" Chipboard Liner (Inside Wall surfaces including Ceiling)
- 4 mil Vapour Barrier
- 2" x 4" Wall Studs at 16" oc
- R-12 (4") Fibreglass Insulation (Walls & Ceiling)
- 1/2" Exterior Sheeting (Buffalo Board)
- Prefinished Masonite Hardboard Lapsiding or equivalent (Shell White)

STAIRS :

- 3' x 4' Landing complete with Handrails (Typical)

WATER STORAGE TANK AREA :

- 2'-6" wide x 5'-6" deep x 6'-6" high inside measurements
- 2" x 4" stud construction
- R-12 (4") Fibreglass Insulation (all panels)
- Panels lined both sides with 3/8" chipboard
- Panels - Top & inside to be removable

BEDROOM CLOSET DETAILS :

- 4 removeable Shelves - 16" deep
- Start Shelves at 24" above Floor - at 16" spacing

DOOR SCHEDULE :

- M : 4 only - 2'-10" x 6'-8" x 13/4"
- N : 3 only - 2'-6" x 6'-8" x 13/8"
- P : 1 only - 2'-0" x 6'-8" x 1 3/8"

WINDOW SCHEDULE :

- Kitchen/Living Room - 4'-0" wide x 3'-6" high
- Office - 4'-0" wide x 3'-0" high
- Bedrooms - 3'-0" wide x 3'-0" high
- Washroom - 2'-0" wide x 3'-0" high

PLUMBING :

- Toilet Crane Radcliff
- Basin Crane Carilton
- Shower Flat Seagul Polyethelene Steel Kit DL 202
- Faucets Waltec Flotral
- Underfloor plumbing to be insulated
- Drainage cock to be located at Lowest point
- Wall plumbing to be surface mounted
- All plumbing to meet Ontario Plumbing Code

ELECTRICAL :

A - 48" Two Lamp Fluorescent C/W wrap around Acrylic Lens
B - 9 volt battery operated Smoke Detectors
C - 1-60 watt Incandescent Superlight x2600
D - 110 volt Smoke Detector interconnected for simultaneous alarm
E - 70 watt L P S "Guldfinger" c/w integral P E Cell
F - 70 watt L P S "Guldfinger" - Switched
G - 100 amp overhead Breaker Service F P E Westco or equal
S - Toggle Switch single pole
⊖ - Duplex convenience outlet
⊖ - Range tye outlet
Ⓣ - Wall Thermostat
▨ - Electrical Panel

HEATING :

H - Furnace - Olsen Duomatic model ML 54 - 54,000 BTU output
J - Hot Water Tank - Oil fired equiv. to Aero CF-32T
- Warm Air Ducts to be under floor and insulated
- Chimney to be complete with integral combustion air
R - Metal framed 1" Screen - removable panel in front of furnace
- Wall between furnace & hot water tank to be only 5'-0" high

M. T. C.

LANSDOWNE HOUSE AIRPORT ACCOMMODATION BUILDING

5419-80

DRAWN BY : W.J.S. 2-84 | CHECKED BY : W.M. 2-84

Scale : 1/4" = 1'-0"

APPENDIX G

LANSDOWNE HOUSE AIRPORT OFFICE/ACCOMMODATION BUILDING MODIFIED ENERGY EFFICIENT LAYOUT, SPECIFICATIONS, AND CONSTRUCTION SCHEDULE

Floor Plan:	See Drawing 1	(Exhibit 4.1)
Building Section:	See Drawing 2	(Exhibit 4.2)
Wall/Eave Detail:	See Drawing 3	(Exhibit 4.3)
Roof/Ceiling Detail:	See Drawing 3	(Exhibit 4.3)
Floor/Foundation Detail:	See Drawing 4	(Exhibit 4.4)
View of South Side:	See Drawing 5	(Exhibit 4.5)

SPECIAL CONSTRUCTION SCHEDULE SPECIFICATIONS:

1. Excavate foundation area
2. Build pressure treated wood foundation and support posts, face foundation and backfill
3. Build main floor
4. Build exterior 2 x 6 frame walls
5. Install prefabricated wood roof trusses
6. Roof building, frame gable ends, and build attic access hatch in one gable end.
7. Install exterior sheathing
8. Frame window and exterior door openings
9. Install windows and doors with vapour barrier strips attached
10. Install exterior wall insulation (R20) in 2 x 6 frame walls and foundation walls
11. Install continuous 6ml vapour barrier on inside of exterior walls, ceiling, and foundation walls, extending the vapour barrier on to subfloor and ground as per Drawing 4, overlapping each join in the vapour barrier at least 6", and sealing each overlap with acoustical sealant (including the window and door strips).

12. Build 2 x 3 secondary exterior vertical strapping wall inside 2 x 6 walls, taking care not to puncture vapour barrier
13. Build interior walls taking care not to puncture ceiling vapour barriers
14. Install R40 ceiling insulation and attic ventilation drain tile through attic hatch
15. Install all plumbing, heating, and electrical systems within the interior walls, floor, and 2 x 3 exterior strapping wall, taking care not to puncture vapour barrier
16. Install underfloor R20 insulation for 2 feet around the house perimeter and retain with aspenite or Tyvek air barrier
17. Install secondary R10 exterior wall insulation in 2 x3 exterior strapping wall
18. Install interior finish
19. Install exterior finish

Windows:	Wood frame (for 9" wall thickness), triple glazed vertical sliding heavy duty aluminum or wood sashes
Doors:	Prehung, preinsulated, preweatherstripped wooden doors in wood frame
Electrical:	As per code with all receptacles and switches in exterior walls using 3" boxes

Heating System:

Furnace: 80,000 Btu/hr oil fired forced air furnace. Must be installed with special attention to clearances and materials for fire protection. Must use prefabricated insulated chimney. Must use drywall finish in furnace room.

Controls: Automatic programmable thermostat capable of a 7 day cycle with up to 4 temperature changes per day.

Water System: Well with submersible pump under furnace room.
200 gallon bulk cold water storage tank in furnace room
60 gallon oil or propane fired hot water heater in furnace room

APPENDIX H

HEAT LOSS CALCULATIONS FOR LANSDOWNE HOUSE AIRPORT OFFICE/ACCOMMODATION BUILDING

APPENDIX H

HEAT LOSS CALCULATIONS FOR LANSDOWNE HOUSE AIRPORT OFFICE/ACCOMMODATION BUILDING

	UNMODIFIED	MODIFIED (ENERGY EFFICIENT)
Windows		
Area	$7m^2$	$7m^2$
RSI	0.78	1.0
Design Δ T	56°C	56°C
Heat loss	500 watts	390 watts
Doors		
Area	$4m^2$	$4m^2$
RSI	0.7	0.7
Design Δ T	56°C	56°C
Heat loss	320 watts	320 watts
Walls		
Area	$69m^2$	$90m^2$
RSI	4.0	5.8
Design Δ T	56°C	56°C
Heat loss	970 watts	870 watts
Ceiling		
Area	$59m^2$	$59m^2$
RSI	3.8	7.3
Design Δ T	56°C	56°C
Heat loss	870 watts	450 watts
Floor		
Area	$59m^2$	$59m^2$

RSI	3.8	1.6
Design ΔT	56°C	16°C
Heat loss	870 watts	590 watts
Infiltration		
Volume	190m^3	190m^3
Air changes per hour	0.75	0.25
Design ΔT	56°C	56°C
Heat Loss	2,670 watts	890 watts
Total:	6,200 watts	3,510 watts
Annual heating load assuming 7500 celsius degree days per year	19,900 kWh/yr	11,300 kWh/yr
Annual fuel oil consumption assuming 0.7 fuel combustion efficiency	2,680 l/yr	1,520 l/yr

APPENDIX I

EXAMPLES OF SUPER ENERGY EFFICIENT DESIGN TECHNIQUES FOR FUTURE MTC AIRPORT OFFICE/ ACCOMMODATION BUILDINGS

APPENDIX I

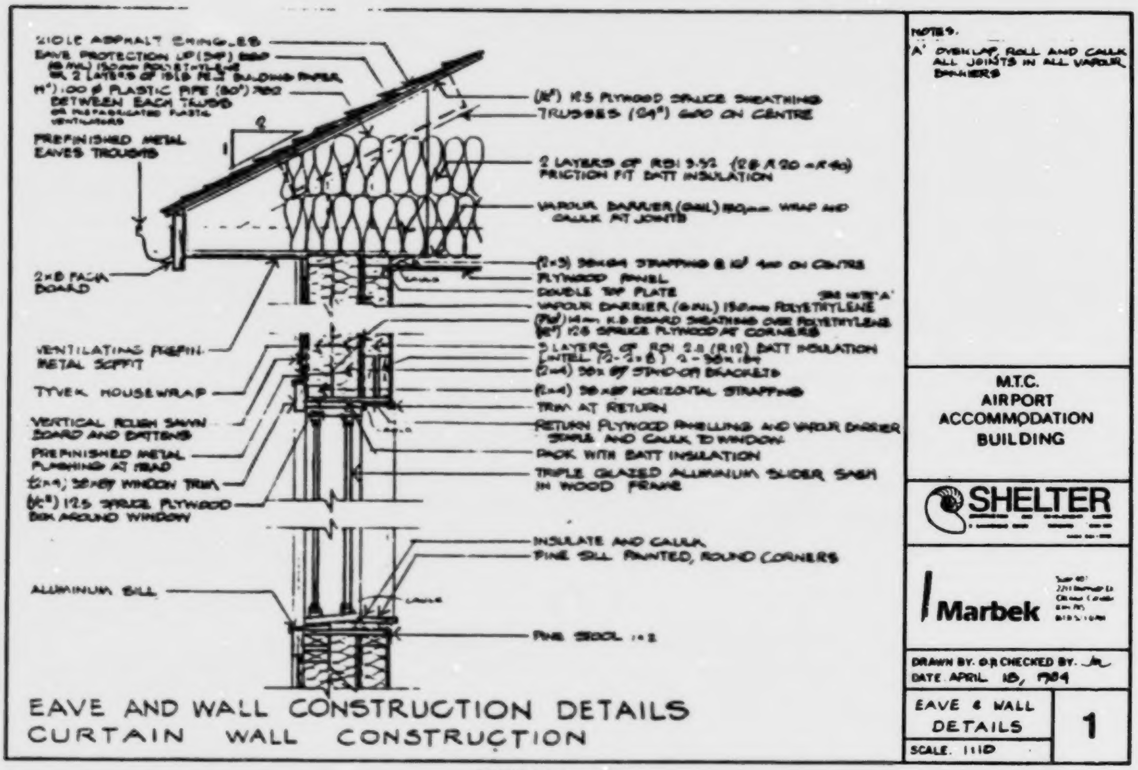
EXAMPLES OF SUPER ENERGY EFFICIENT DESIGN TECHNIQUES FOR FUTURE MTC AIRPORT OFFICE/ACCOMMODATION BUILDINGS

The following material is included in this Appendix to illustrate building techniques and heating and ventilation equipment for super energy efficient housing that require installation by personnel with some experience:

1. Detailed illustration of curtain-wall construction (Exibit 4.6 and 4.7)

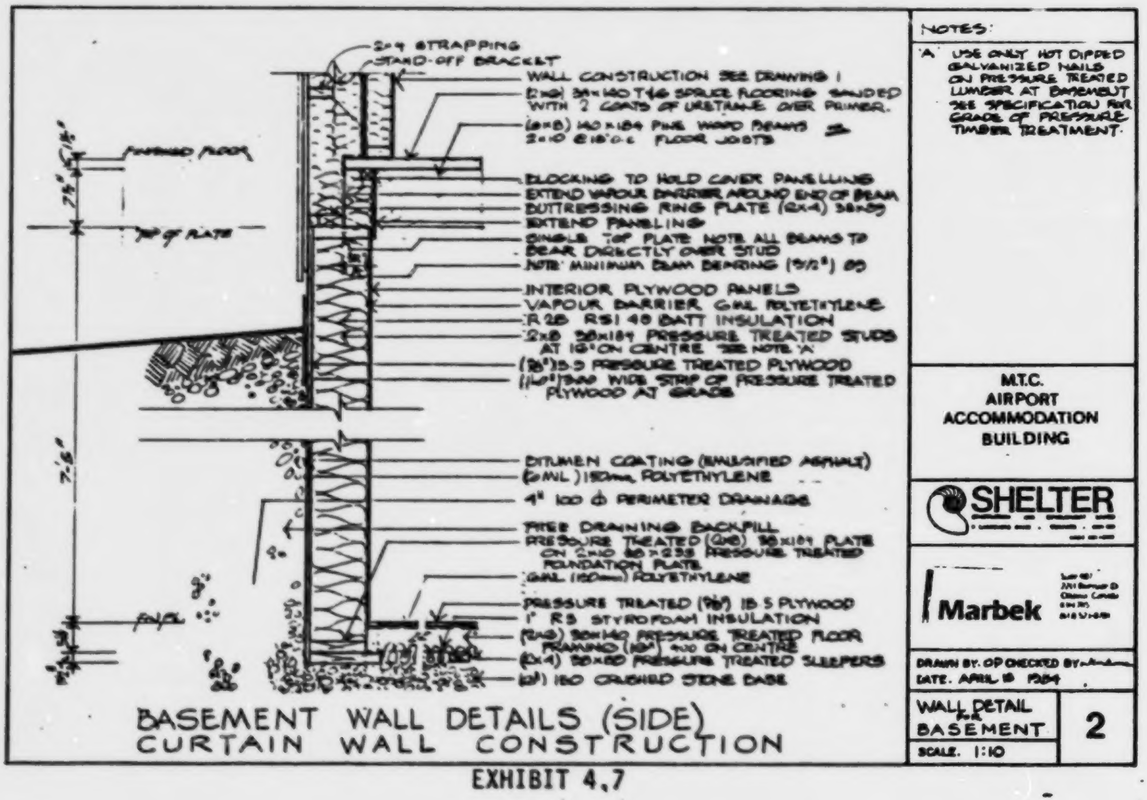
2. Example of a fully condensing single unit oil fired boiler, hot water heater, and forced air heating system

3. Examples of some Canadian air to air heat exchanger systems.



210LE ASPHALT SHINGLES
EAVE PROTECTION UP (3'0") 900
(6 MIL) 150mm POLYETHYLENE
OR 2 LAYERS OF 15LB FELT BUILDING PAPER
(4") 100 Ø PLASTIC PIPE (30") 760
BETWEEN EACH TRUSS
OR PREFABRICATED PLASTIC VENTILATORS
PREFINISHED METAL EAVES TROUGHS
2x8 FACIA BOARD
VENTILATING PREFIN. METAL SOFFIT
TYVEK HOUSEWRAP
VERTICAL ROUGH SAWN BOARD AND BATTENS
PREFINISHED METAL FLASHING AT HEAD
(1x4) 38x89 WINDOW TRIM
(½") 12.5 SPRUCE PLYWOOD BOX AROUND WINDOW
ALUMINUM SILL
(½") 12.5 PLYWOOD SPRUCE SHEATHING
TRUSSES (24") 600 ON CENTRE
2 LAYERS OF RSI 3.52 (2@ R20 = R40) FRICTION FIT BATT INSULATION
VAPOUR BARRIER (6MIL) 150mm WRAP AND CAULK AT JOINTS
(1x3) 38x64 STRAPPING @ 16" 400 ON CENTRE
PLYWOOD PANEL
DOUBLE TOP PLATE
SEE NOTE 'A'
VAPOUR BARRIER (6 MIL) 150mm POLYETHYLENE
(⅝") 14mm K.D BOARD SHEATHING OVER POLYETHYLENE
(½") 12.5 SPRUCE PLYWOOD AT CORNERS
3 LAYERS OF RSI 2.1 (R12) BATT INSULATION
LINTEL (2-2x8) 2-38x184
(2x4) 38x89 STAND-OFF BRACKETS
(2x4) 38x89 HORIZONTAL STRAPPING
TRIM AT RETURN
RETURN PLYWOOD PANELLING AND VAPOUR BARRIER STAPLE AND CAULK TO WINDOW
PACK WITH BATT INSULATION
TRIPLE GLAZED ALUMINUM SLIDER SASH IN WOOD FRAME
INSULATE AND CAULK
PINE SILL PAINTED, ROUND CORNERS
CAULK
PINE STOOL 1x2
EAVE AND WALL CONSTRUCTION DETAILS
CURTAIN WALL CONSTRUCTION
NOTES.
'A' OVERLAP, ROLL AND CAULK ALL JOINTS IN ALL VAPOUR BARRIERS
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
SHELTER
Marbek
DRAWN BY. O.R CHECKED BY.
DATE APRIL 18, 1984
EAVE & WALL DETAILS
SCALE. 1:10
1

EXHIBIT 4.6



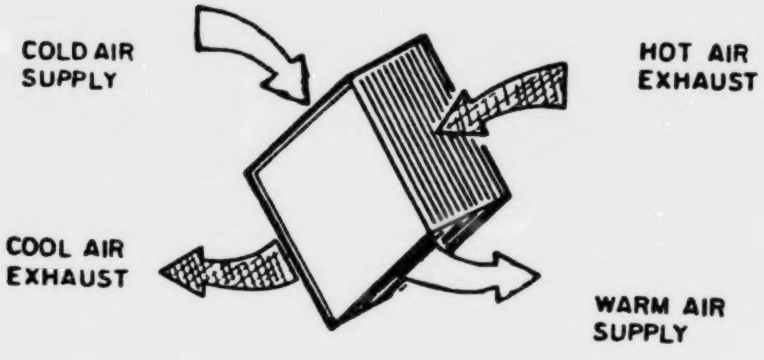
2x4 STRAPPING
STAND-OFF BRACKET
FINISHED FLOOR
TOP OF PLATE
7'-6"
F.N.F.L.
WALL CONSTRUCTION SEE DRAWING 1
(2x6) 38x140 T&G SPRUCE FLOORING SANDED WITH 2 COATS OF URETHANE OVER PRIMER.
(6x8) 140x184 PINE WOOD BEAMS 2x10 @16" o.c. FLOOR JOISTS
BLOCKING TO HOLD COVER PANELLING
EXTEND VAPOUR BARRIER AROUND END OF BEAM
BUTTRESSING RING PLATE (2x4) 38x89
EXTEND PANELLING
SINGLE TOP PLATE NOTE ALL BEAMS TO BEAR DIRECTLY OVER STUD
NOTE: MINIMUM BEAM BEARING (3½") 89
INTERIOR PLYWOOD PANELS
VAPOUR BARRIER 6 MIL POLYETHYLENE
R28 RSI 4.9 BATT INSULATION
2x8 38x184 PRESSURE TREATED STUDS AT 16" ON CENTRE SEE NOTE 'A'
(⅝") 15.5 PRESSURE TREATED PLYWOOD
(1'-0") 300 WIDE STRIP OF PRESSURE TREATED PLYWOOD AT GRADE
BITUMEN COATING (EMULSIFIED ASPHALT)
(6 MIL) 150mm POLYETHYLENE
4" 100 Ø PERIMETER DRAINAGE
FREE DRAINING BACKFILL
PRESSURE TREATED (2x8) 38x184 PLATE ON 2x10 38x235 PRESSURE TREATED FOUNDATION PLATE
6 MIL (150mm) POLYETHYLENE
PRESSURE TREATED (⅝") 15.5 PLYWOOD
1" R5 STYROFOAM INSULATION
(2x6) 38x140 PRESSURE TREATED FLOOR FRAMING (16") 400 ON CENTRE
(2x4) 38x89 PRESSURE TREATED SLEEPERS
(6") 150 CRUSHED STONE BASE
BASEMENT WALL DETAILS (SIDE)
CURTAIN WALL CONSTRUCTION
NOTES:
'A' USE ONLY HOT DIPPED GALVANIZED NAILS ON PRESSURE TREATED LUMBER AT BASEMENT SEE SPECIFICATION FOR GRADE OF PRESSURE TIMBER TREATMENT.
M.T.C.
AIRPORT
ACCOMMODATION
BUILDING
SHELTER
Marbek
DRAWN BY. OP CHECKED BY.
DATE. APRIL 18 1984
WALL DETAIL FOR BASEMENT
SCALE. 1:10
2

EXHIBIT 4.7

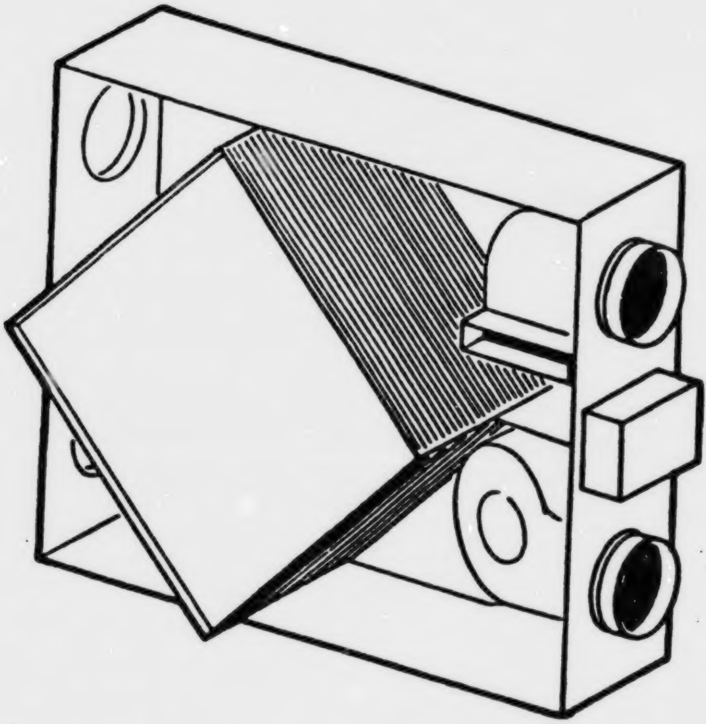
AIR-TO-AIR HEAT EXCHANGERS AVAILABLE IN CANADA

Manufacturer or Distributor	Model Name	Type of Heat Exchanger	Core Material	Air Flows (L/s)	Defrost	Controls	Remarks
1) Air Changer Company	D-150	Plate	Polypropylene	30-75	Shut down of fresh air by thermostat	Two Speed: low speed, adjustable; high speed, from humidstat or external switch	
2) Blackhawk Industries	Blackhawk 15	Plate	Polystyrene	50 (high speed)	Shut down of fresh air by timer and/or electric preheat	Two speed: High speed, from humidstat, or automatic 10 minute duration photoelectric switch, or manual override	
	Blackhawk 25	Plate	Polystyrene	70 (high speed)	ditto	ditto	
3) Conservation Energy Systems (CES)	VANEE R-200	Plate	Polyolefin	30-118	Shut down of fresh air by thermostat	Two Speed: low speed, adjustable; high speed, from humidstat or external switch	
	VANEE P-7005	Plate	Polyolefin		Intermittent operation Recirculation Electric preheat		Fans not included
4) ENER-CORP Management Ltd.	Enerex	Plate	ABS plastic	75-100 (high speed)	Frost prevention by control of fresh air fan	Two speed: low speed adjustable; high speed adjustable; humidstat or external switch to activate high speed	
5) Environment Air Ltd.	EnviroXChanger:						
	HP 135	Heat Pipe	Aluminum	65	No defrost	All models: One speed adjustable wall mounted speed setting. On/off by humidistat.	
	HP 160	Heat Pipe	Aluminum	75	Shut down of fresh air by thermostat		
	HP 200	Heat Pipe	Aluminum	95			
	HP 265	Heat Pipe	Aluminum	125			
	HP 320	Heat Pipe	Aluminum	150			
6) Indusco Sales	FLX005	Plate	Aluminum	60			Fans not included
	MPS 50/350	Plate	Aluminum	350			Fans not included
7) Lennox	Deluxe Air Changer	Plate	Polypropylene	30-75	Shut down of fresh air by thermostat	Two Speed: low speed, adjustable; high speed, from humidstat or external switch	
8) Nutech Energy Systems Ltd.	Lifebreath 130	Plate	Aluminum	61	Automatic demand electric preheat	Low/med/high switch on heat exchanger	
	Lifebreath 250	Plate	Aluminum	110	ditto	ditto	
9) Airxchange Inc. (Nutone of Canada)	Air-X-Change 502	Rotary	Polystyrene	45-95 (high speed)	Not required	Two speed: low speed adjustable; high speed adjustable. Low speed/high speed from manual switch	will be available April 1984 through Nutone
10) P.M. Wright	Fan-X-Changer WR25-2	Capillary Blower	Polyurethane Foam	100 (high speed)	Not required	Variable speed	humidity transfer
	Fan-X-Changer WR32-16-4	Capillary Blower	Polyurethane Foam	337 (high speed)	Not required	Two speed	humidity transfer
11) Fabrication Z-Air Inc.	Z-Vent 2020	Plate	Aluminum Foil	17-70	Preheat	Humidstat, timer or external switch	
12) Zero Energy Products	Heat X-changer PLX-40	Plate	Treated paper or plastic	116	Preheat	Two Speed: low speed, adjustable; high speed, from humidstat or manual switch	humidity transfer with paper core.

SCHEMATIC OF A PLATE-TYPE HEAT EXCHANGER CORE


COLD AIR
SUPPLY
HOT AIR
EXHAUST
COOL AIR
EXHAUST
WARM AIR
SUPPLY

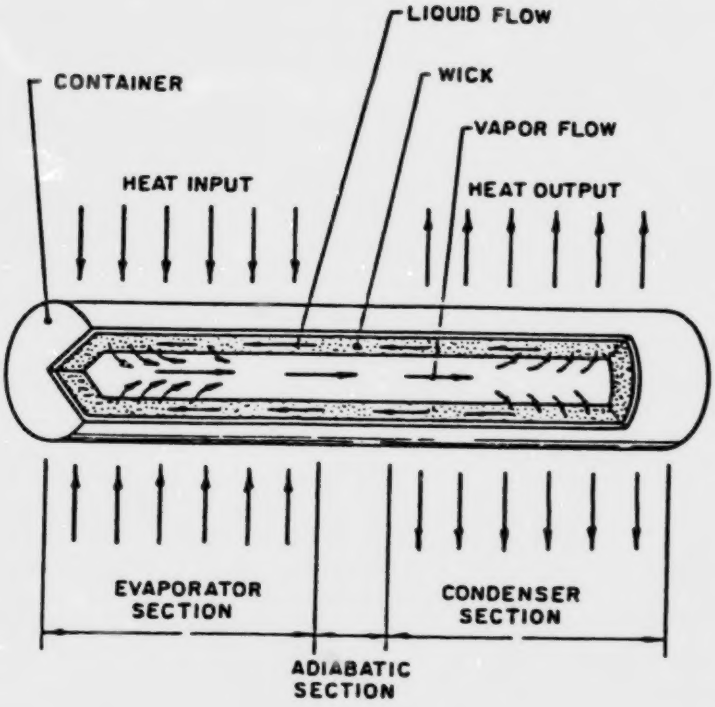
A)

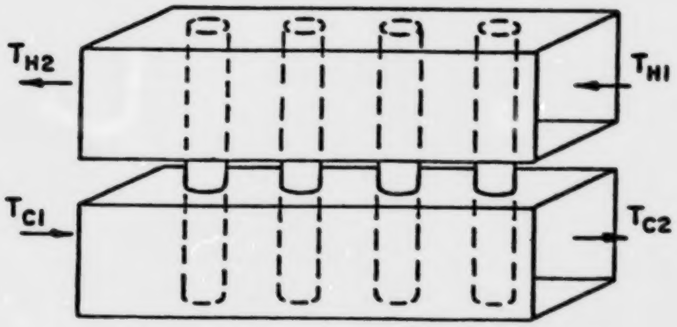


B)

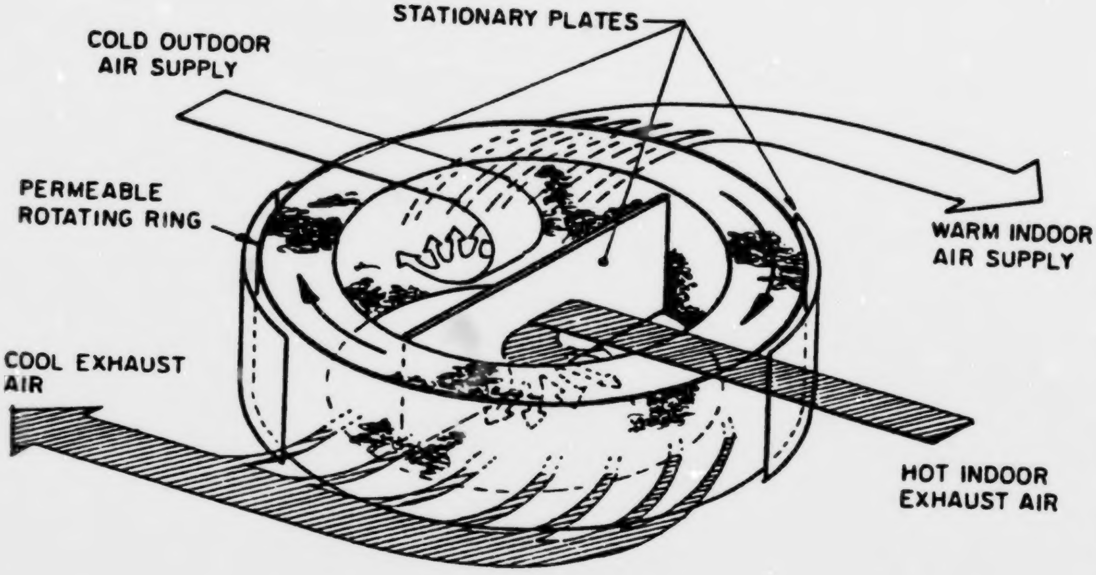
a) Schematic of a Plate-Type Heat Exchanger Core
b) Cut-Away View of a Plate-Type Heat Exchanger

SCHEMATIC OF A HEAT PIPE HEAT EXCHANGER

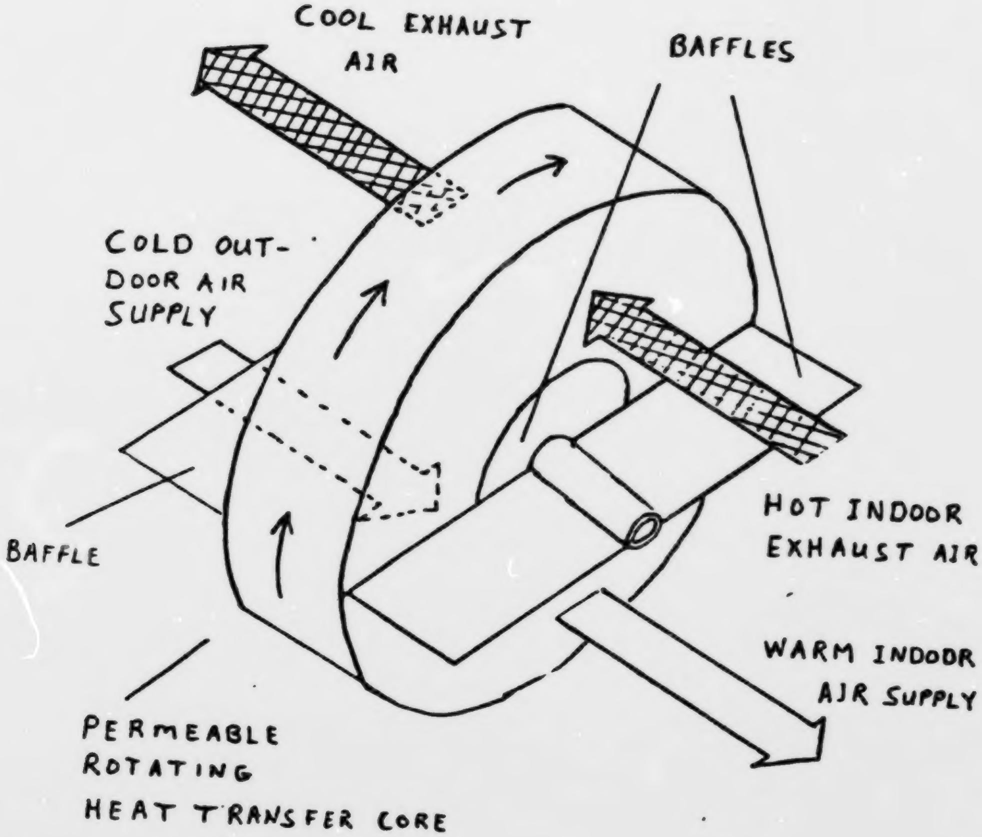

LIQUID FLOW
CONTAINER
WICK
VAPOR FLOW
HEAT INPUT
HEAT OUTPUT
EVAPORATOR SECTION
CONDENSER SECTION
ADIABATIC SECTION


T_{H2}
T_{H1}
T_{C1}
T_{C2}

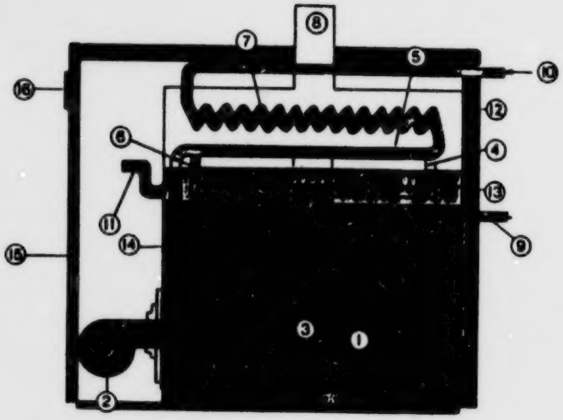
SCHEMATIC OF A CAPILLARY BLOWER HEAT EXCHANGER


STATIONARY PLATES
COLD OUTDOOR AIR SUPPLY
PERMEABLE ROTATING RING
WARM INDOOR AIR SUPPLY
COOL EXHAUST AIR
HOT INDOOR EXHAUST AIR

SCHEMATIC OF A ROTARY HEAT EXCHANGER

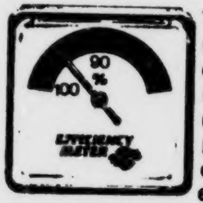

COOL EXHAUST AIR
BAFFLES
COLD OUT-DOOR AIR SUPPLY
BAFFLE
HOT INDOOR EXHAUST AIR
WARM INDOOR AIR SUPPLY
PERMEABLE ROTATING HEAT TRANSFER CORE

F L A M E C O R



Patented design

1. Combustion chamber stainless steel (316L)
2. Burner with electronic ignition
3. Combustion tubes stainless steel (316L)
4. Bubblecap, 1st stage flue gas heat reclaimer, stainless steel (316L)
5. Watercooled top, stainless steel (316L) — 2nd stage flue gas heat reclaimer
6. Bubblecap fins, stainless steel (316L)
7. 3rd stage flue gas heat reclaimer stainless steel (316L)
8. Exhaust pipe, plastic
9. Outlet supply water
10. Inlet return water
11. Outlet condensate overflow-to standard drain
12. Condensate tray, (316L) stainless steel
13. Antipulsation tray stainless steel (316L)
14. Heated water
15. Easy access cabinet
16. Efficiency meter & temperature gauges



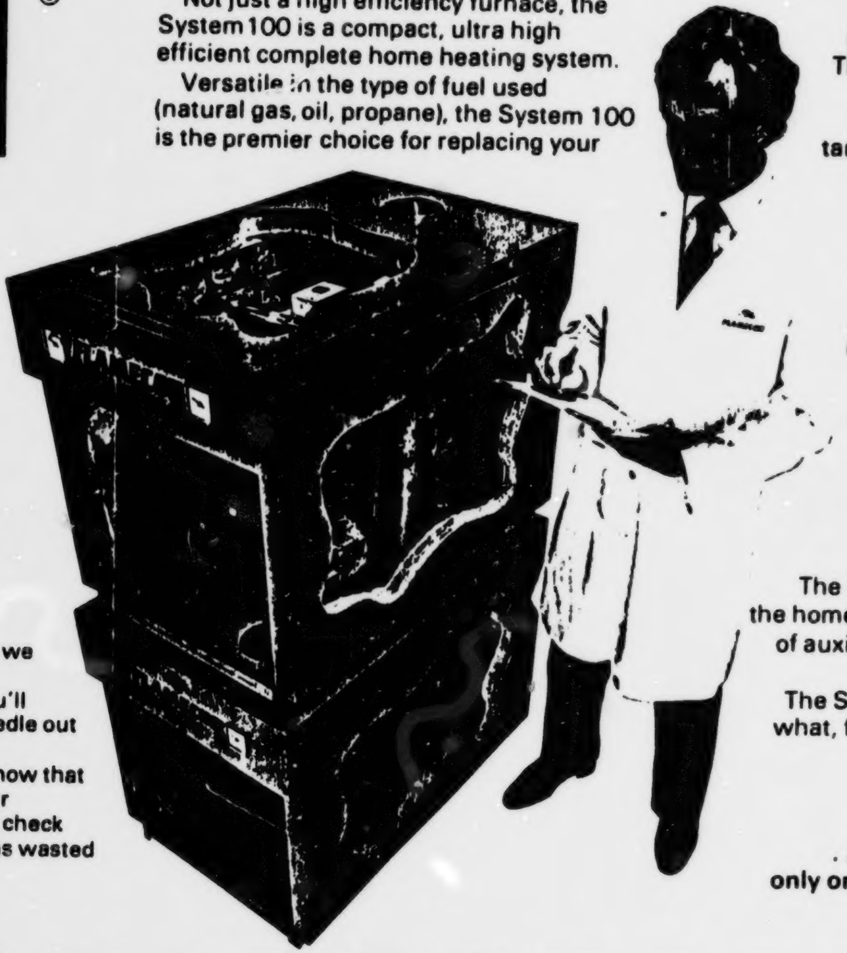
THE WATCHDOG

Others talk about high efficiency. We show it and we monitor it. With proper maintenance and care, you'll probably never see the needle out of the 90's but having the efficiency meter lets you know that you're getting the maximum output from your System 100. Only Flamecor tells you when a check up is necessary. An inefficient furnace means wasted fuel dollars. We save them.

Whisper quiet, efficient, and engineered to provide the homeowner with a total home heating system that is safe, reliable, and economical, the Flamecor System 100 is the result of intensive advanced research and development. Only state-of-the-art technology, components and the finest of materials are used in the manufacture of the System 100.

Not just a high efficiency furnace, the System 100 is a compact, ultra high efficient complete home heating system.

Versatile in the type of fuel used (natural gas, oil, propane), the System 100 is the premier choice for replacing your existing furnace or boiler and for hew home installation.



The unique design of the System 100 also enables you to heat additions to your home and effectively heat the basement and other troublesome cold spots without major alterations to your heating system.

The zero clearance or closet installation capability of the System 100 gives the homeowner a choice of system location. This provides you with additional useable living space.

The stainless steel domestic hot water tank (option) maximizes your fuel dollar by using the ultra high efficiency and three stage heat reclaiming features of the System 100. A standard hot water tank uses up to 30% of your annual heating bill. The air processor option enables the home-owner to use the System 100 for forced air applications. This design provides quiet comfortable heat, and eliminates air scorching.

Greater personal comfort can be easily attained by quick installation of Flamecor's optional electronic air purifier in the air processor.

There's more!

The System 100's amazing flexibility allows the homeowner to adapt his system for a variety of auxiliary home uses including heating your swimming pool, hot tub or whirlpool.

The System 100 is a cost efficient addition to what, for most of us, is our single, largest and most important life time investment . . . our home.

. . . the Flamecor System 100 comes in only one decorator colour . . . SOLID GOLD.

Features and Benefits

System versatility
Designed to easily fit into your existing forced air ductwork, hydronic system or create a combination of both.

Fuel source versatility
The System 100 is designed to operate on natural gas, oil, or propane at the same efficiency.

System conversion
The System 100 can be easily converted to natural gas, oil or propane.

All stainless steel construction
316L stainless steel construction adds durability and dramatically increases the life span of your heating system.

Super quiet operation
Totally insulated cabinets give whisper quiet operation, reducing cabinet heat loss and allowing zero clearance/closet installation.

Domestic hot water heating capability
Quicker, cheaper, more efficient supply of domestic hot water. What a savings!

Patented design
Annual fuel use efficiency (A.F.U.E.) up to 96%. Year round high energy efficiency means fuel bill savings.

Compact size
So compact, so versatile, that you can install your System 100 in a closet, in your kitchen, or in the alcove under your stairs.

Fan coil type air processor
Eliminates air scorching. Provides greater home comfort.

Full range of sizes, options and accessories
Totally integrated, domestic hot water heater, air processor for forced air systems, electronic air purifier, swimming pool/hot tub and whirlpool heater.

No chimney required
Through the wall vent allows you to save space and money on new home construction or renovations.

Home centre flexibility
The System 100 can be easily adapted to heat your swimming pool/hot tub or whirlpool bath.

10 year warranty
Peace of mind backed by a system designed, tested, and CGA approved for Canadian conditions.

Efficiency meter
You know that you are receiving maximum efficiency from your System 100.

Cabinet Finish
Heavy guage satin coat steel painted with primer and finished coat of heat resistant acrylic. Longer equipment life.

APPROVED

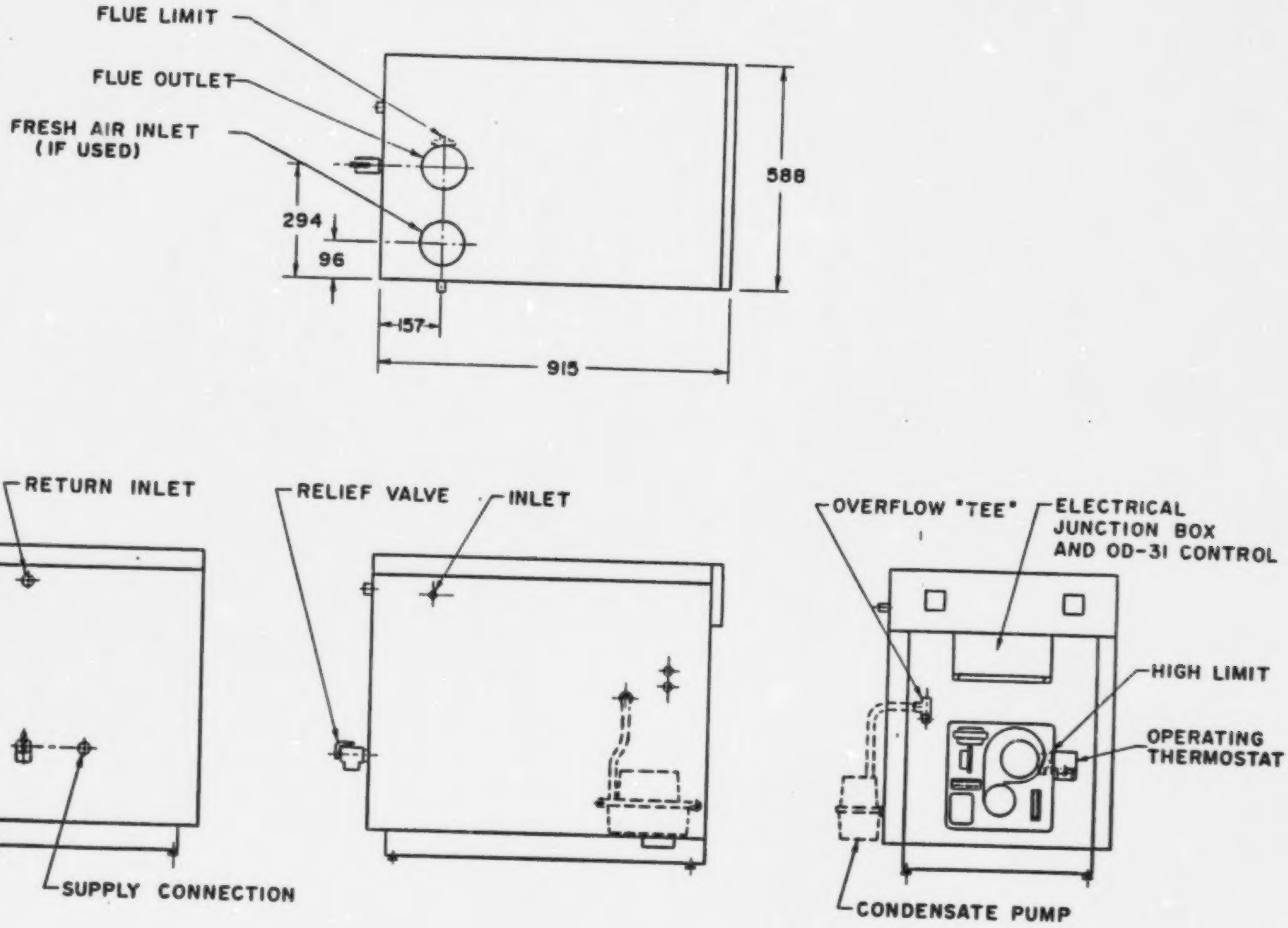
FLAMECOR

ENERGY PRODUCTS INC.

99 Bruce Crescent, Carleton Place, Ontario K7C 3T3
Carleton Place (613) 257-3165
Ottawa (613) 237-0333
Telex: 053-3874

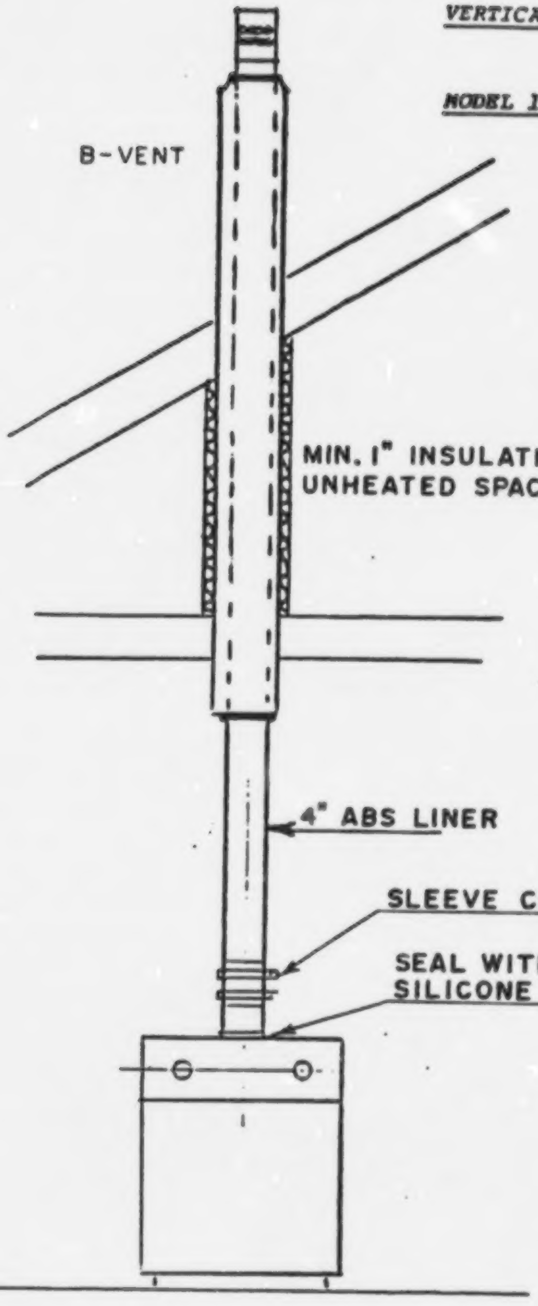
In United States contect,
HADWICK CORPORATION, P.O. BOX 3265,
NEW HAVEN, CONN. 06515

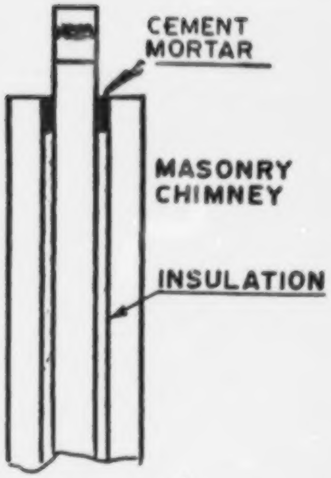
THE GOLD AGE
FLAMECOR
SYSTEM 100

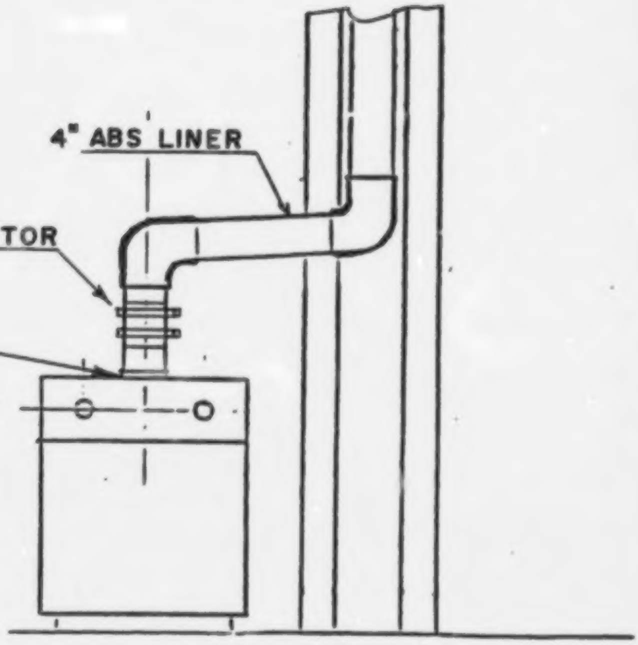

FLUE LIMIT
FLUE OUTLET
FRESH AIR INLET (IF USED)
294
96
157
915
588
RETURN INLET
725
SUPPLY CONNECTION
RELIEF VALVE
INLET
OVERFLOW "TEE"
ELECTRICAL JUNCTION BOX AND OD-31 CONTROL
HIGH LIMIT
OPERATING THERMOSTAT
CONDENSATE PUMP

VERTICAL VENTING

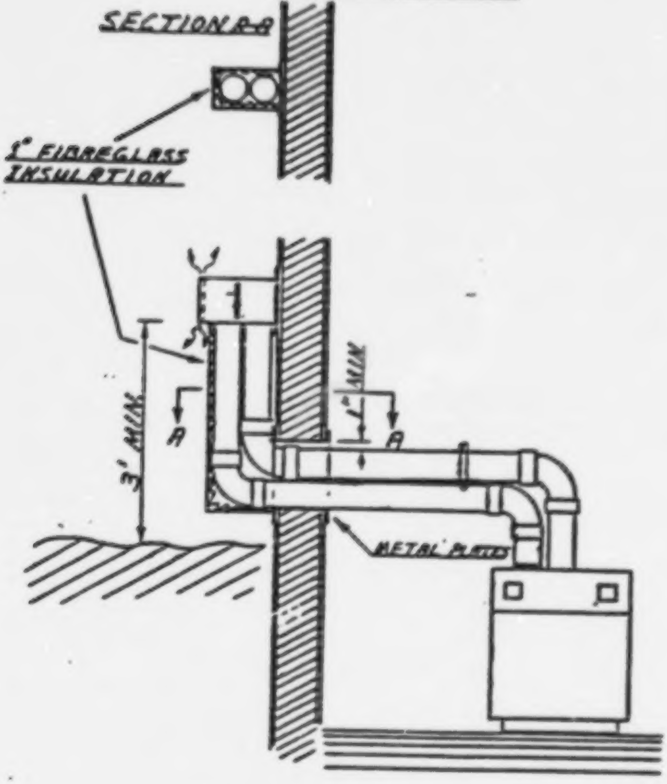
MODEL 110

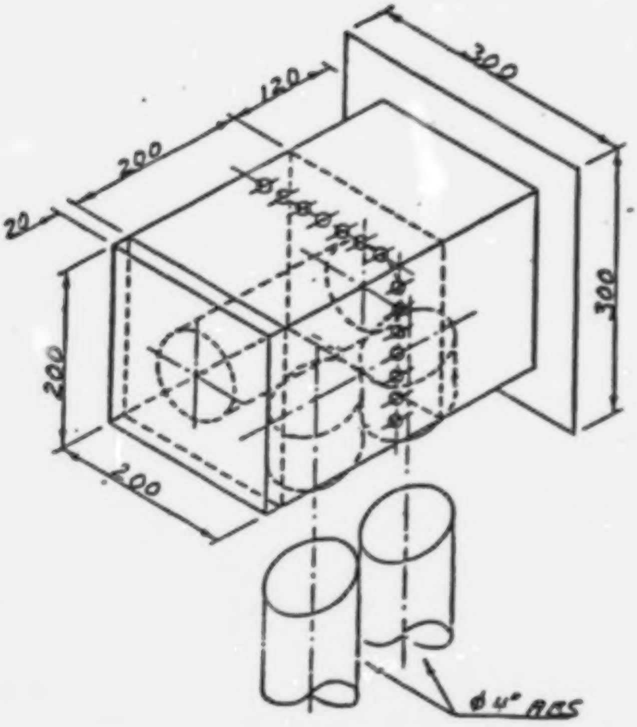

B-VENT
MIN. 1" INSULATION IN UNHEATED SPACE
4" ABS LINER
SLEEVE CONNECTOR
SEAL WITH SILICONE


CEMENT MORTAR
MASONRY CHIMNEY
INSULATION

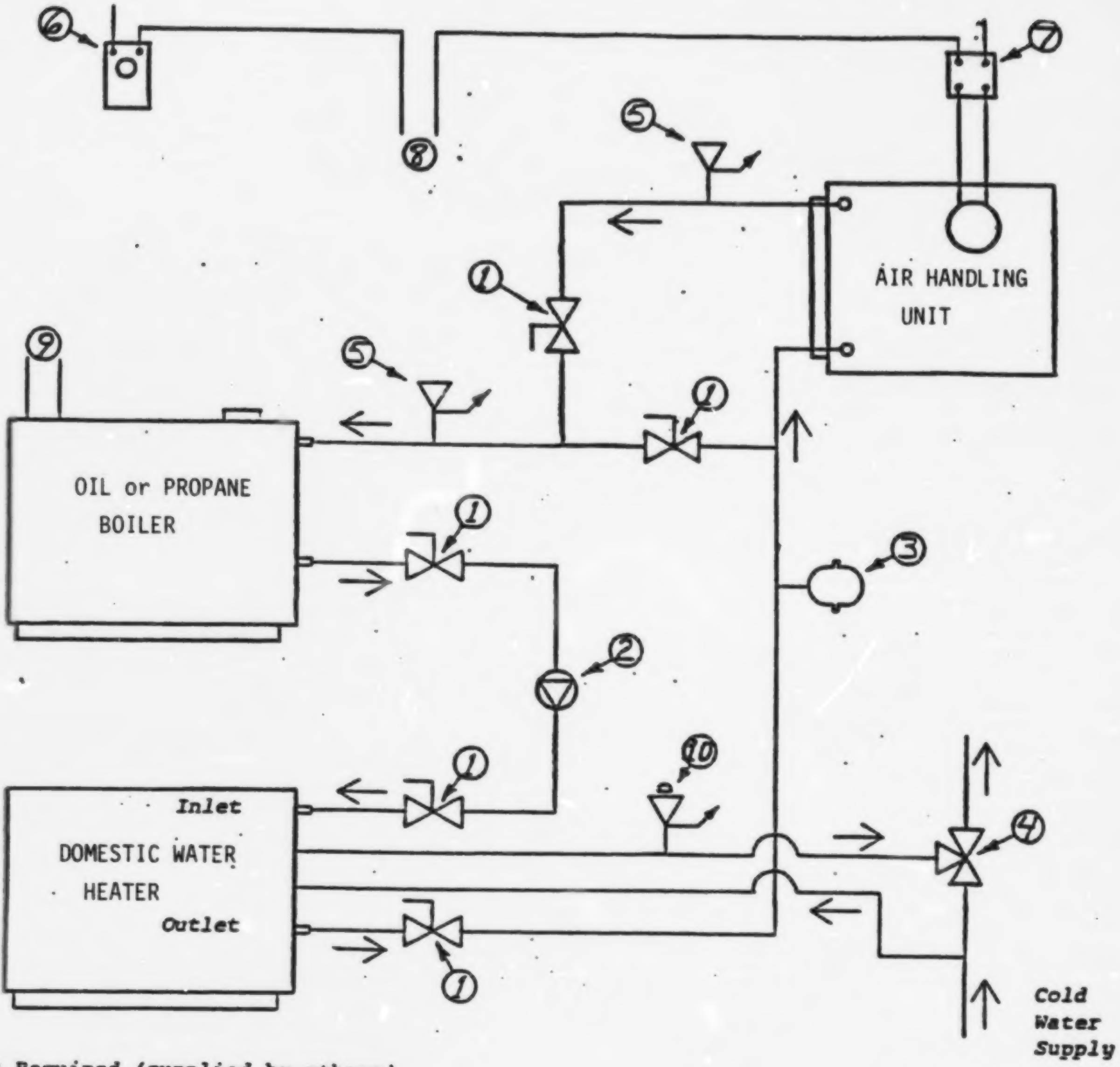


Horizontal Venting


SECTION A-A
1" FIBREGLASS INSULATION
3' MIN
A
1" MIN
A
METAL PLATES


300
120
200
20
300
200
200
ϕ 4" ABS

MODEL 112


⑥
⑦
⑧
⑤
AIR HANDLING UNIT
①
⑨
⑤
①
OIL or PROPANE BOILER
①
③
②
⑩
①
Inlet
DOMESTIC WATER HEATER
Outlet
④
①
Cold Water Supply

Equipment Required (supplied by others)

Qty	*Key No.*	*Description*
4	*1*	*Shut Off/Gate Valves*
1	*2*	*Circulating Pump*
1	*3*	*Pressurized Expansion Tank*
1	*4*	*Tempering Valve, for example Watts Model 70A or T*
2	*5*	*Automatic Air Vents*
1	*6*	*Thermostat*
1	*7*	*Relay (Fan Motor)*
1	*8*	*110V/24V Transformer*
	9	*110V AC Supply to Boiler*
1	*10*	*Relief Valve, 125 psi*

Note: Tempering Valve will mix 160°F D.H.W. with cold water to reduce it to 140°F.

Installation of Flamecor 104-108 to 150 to 101

108 M4 097
83 11 14

APPENDIX J

WINISK AIRPORT ENERGY AUDIT CALCULATIONS

APPENDIX J

WINISK AIRPORT ENERGY AUDIT CALCULATIONS

Assumptions: Design Temperatures & Degree Days

The following exterior design temperatures and degree days were used:

Average heating season temperature:	-12°C
Design temperature (air):	-38°C
Design Temperature (ground):	2°C
Design degree days below 18°C:	8600

Interior design temperatures: These are assumed to be as follows:

Hotel	18°C
House	18°C
Waiting Room:	18°C[1]

---

[1] The waiting room at Winisk tends to be kept warmer than at other airports because it houses the Austin Airways agent office.

Winisk Airport Hotel

	Construction	Thermal Resistance (RSI) walls/°C/m^2	Number	Dimensions	Area
Doors	wood (75mm)	0.7	3	1m X 2m	6m^2
Windows	double pane (metal)	0.7	12	1m X 2m	24m^2
Walls (excluding doors & windows)	wood frame with strapping fibreglass insulation (140mm) plywood siding	3.8	2	30m X 2.5m	130m^2
			2	9.5m X 2.5m	
Ceiling	wood frame fibreglass insulation (140mm average) ceiling tile	3.7	1	30m X 7m	220m^2
			1	4m X 2.5m	
Floor	cement pad floor tile	0.8	1	30m X 7m	220m^2
			1	4m X 2.5m	

CONDUCTION HEAT LOSS = $\frac{\text{Design temperature difference X Area}}{\text{RSI}}$ **(watts)**

Design temperature difference (floor) = 18 - 2 = 16°C

Design temperature difference (other) = 18 - (-38) = 56°C

therefore Conduction heat loss =

$$\frac{56 \times 30}{0.7} + \frac{56 \times 130}{3.8} + \frac{56 \times 220}{3.7} + \frac{16 \times 220}{0.8}$$

= 12,050 watts

INFILTRATION HEAT LOSS = 0.335 X Hotel Volume X Design temperature difference X number of air changes per hour (watts)

Hotel volume = $650 m^3$

Assumed air changes per hour equal to 0.75, the building being of average air tightness.

Therefore: **Infiltration heat loss** = 0.335 X 650 X 56 X 0.75
= 9150 watts

Therefore: **Total design heat loss** = 12,050 + 9,150
= 21,200 watts

Annual heating load = $\frac{\text{Design heat loss X 24}}{\text{Design temperature difference}}$

$$= \frac{21{,}200 \times 24}{56}$$

= 9100 Wh/Degree day

= 9100 X 8600

= 78,200 kWh/year

Assuming a 65% fuel burner efficiency and an oil heating value of 10.6 kWh/litre;

Annual fuel consumption = $\frac{78{,}200}{10.6 \times 0.65}$

= 11,400 litres/year

Winisk Airport Manager's House

	Construction	Thermal Resistance (RSI) walls/°C/m^2	Number	Dimensions	Area
Doors	wood (75mm)	0.7	1	2m X 1m	2m^2
Windows	double pane	0.7	5	0.8mX1.75m	7m^2
Walls	wood frame with strapping fibreglass insulation (140mm) plywood panelling	3.8	2 2	6m X 2.5m 9m X 2.5m	66m^2
Ceiling	wood frame fibreglass insulation (90mm est.) ceiling tile	2.4	1	6m X 9m^2	54m^2
Floor	wood frame fibreglass insulation (90mm est.) carpet plywood	2.4	1	6m X 9m^2	54m^2

$$\textbf{CONDUCTION HEAT LOSS} = \frac{\textbf{Design temperature difference X Area}}{\textbf{RSI}}\textbf{(watts)}$$

Design temperature difference = 18 - (-38) = 56°C

Therefore Conduction heat loss =

$$\frac{56 \times 9}{0.7} + \frac{56 \times 66}{3.8} + \frac{56 \times 54}{2.4} + \frac{56 \times 54}{2.4}$$

$$= 4210 \text{ watts}$$

INFILTRATION HEAT LOSS = 0.335 X House volume X Design temperature difference X Number of air changes per hour (watts)

House volume = $135m^3$

Assumed air changes per hour assumed equal to 1.5 because of low air tightness

Therefore: **Infiltration heat loss** = 0.335 X 135 X 56 X 1.5
= 3800 watts

Therefore: **Total design heat loss** = 4210 + 3800
= 8010 watts

Annual heating load $= \frac{\text{Design heat loss X 24}}{\text{Design temperature difference}}$

$= \frac{8010 \text{ X } 24}{56}$

= 3430 Wh/Degree day

= 3430 X 8600

= 29,500 kWh/year

Assuming a 65% fuel burner efficiency and an oil heating value of 10.6 kWh/litre:

Annual fuel consumption $= \frac{29{,}500}{10.6 \text{ X } 0.65}$

= 4300 litres/year

Winisk Airport Waiting Room

	Construction	Thermal Resistance (RSI) walls/°C/m²	Number	Dimensions	Area
Doors	Wood (75mm)	0.7	2	1m X 2m	4m²
Windows	double pane (metal)	0.7	3	1m X 1m	3m²
Walls	wood frame with strapping fibreglass insulation (140mm est.) plywood (2)	3.8	4	6m X 2.5m	53m²
Ceiling	wood frame fibreglass insulation (140mm est.) plywood	3.8	1	6m X 6m	36m²
Floors	wood frame plywood	0.4	1	6m X 6m	36m²

$$\textbf{CONDUCTION HEAT LOSS} = \frac{\textbf{Design temperature difference X Area}}{\textbf{RSI}}\textbf{(watts)}$$

Design temperature difference = 18 - (-38°) = 56°C

Therefore: **Conduction heat loss =**

$$\frac{56 \text{ X } 7}{0.7} + \frac{56 \text{ X } 53}{3.8} + \frac{56 \text{ X } 36}{3.8} + \frac{56 \text{ X } 36}{0.4}$$

= 6920 watts

INFILTRATION HEAT LOSS = 0.335 X Building volume X Design temperature difference X Number of air changes per hour (watts)

Building volume = $90m^3$

Assumed air changes per hour equal to 1.0 because of leaky windows.

Therefore: **Infiltration heat loss** = 0.335 X 90 X 56 X 1.0
= 1690 watts

Therefore: **Total design heat loss** = 1690 + 6820
= 8610 watts

$$\textbf{Annual heating load} = \frac{\textbf{Design heat loss X 24}}{\textbf{Design temperature difference}}$$

= 3690 Wh/Degree Day

= 3690 X 8600

= 31,800 kWh/year

Assuming a 50% fuel stove efficiency and an oil heating value of 10.6 kWh/litre:

$$\textbf{Annual fuel consumption} = \frac{31,800}{10.6 \text{ X } 0.5}$$

= 6000 litres/yr.

Winisk Airport Power Generators:

Generator set ratings:	75 kW Harper
Engines(3):	Detroit Diesel, Model 4-71N, 284 cu.in, 1800 rpm, 2 cycle, naturally aspirated (positive displacement scavenger blower), liquid cooled (glycol/water, 6HP fan), 115 maximum HP at 1800 rpm.
Generators (3):	Stanford, 75kW, 97.5 kVA, 0.8 power factor, 120/208 volt, 3 phase, four wire, 60 cycle

Measured load at 1pm and 9pm was 20kW (25kVA)
The engine is therefore running at about 27% of capacity.

Assuming an 80% generator efficiency because of the low load:

Engine shaft horsepower = $\frac{20}{0.746 \times 0.8}$

= 33.5 BHP

Assuming a fuel consumption of 0.5 lbs/BHP/hr because of low load:

Engine fuel consumption = 33.5 X 0.5

= 16.75 lbs/hr

= 9.0 litres/hr

At a fuel heat value of 10.6 kWh/litre, the total heat production
= 10.6 X 9.0
= 95.4 kW

Therefore: **Generator set efficiency** = 20/95.4
= 21%

With a generator efficiency of 80%

Engine efficiency = $\frac{21\%}{0.8}$

= 26%

Therefore: **Engine losses** = 74%

At 27% loading about 20% of engine heat is lost through radiation and lube oil losses, therefore about 54% or 50 kW of engine heat is potentially recoverable from the exhaust and radiator.

The observed exhaust temperature was only 250°C however. At this temperature only about 25% of exhaust heat is recoverable.

Assuming equal amounts of heat are potentially recoverable from the exhaust and radiator, the practical amount of heat recovery is therefore about 32,500 watts (222,000 Btu/hr)

At present, heat is being recovered only from the radiator and being used to heat the garage and workshop, therefore the amount of heat actually being recovered at a 20kW load is about 25,000 watts (85,000 Btu/hr)

Estimated heat losses from garage, power room and workshop:

	Construction	**Thermal Resistance** (RSI) walls/°C/m²	**Number**	**Dimensions**	**Area**
Walls	wood frame fibreglass insulation (90mm) plywood (2)	2.4	2 2 1 1	8m X 5m 7m X 3m 30m X 3m 22m X 3m	280
Ceiling	wood frame fibreglass insulation (140mm) plywood	3.8	1 1	8m X 8m 30m X 7m	275
Floor	cement pad	0.4	1 1	8m X 8m 30m X 7m	275

INSTANTANEOUS CONDUCTION HEAT LOSS =

$$\frac{\textbf{Temperature Difference X Area}}{\textbf{RSI}}\ \textbf{(watts)}$$

If average inside temperature = T°C

Temperature difference (floor) = T-2°C

Temperature difference (other) = T+38°C

Therefore: **Instantaneous conduction heat loss**

$$= \frac{(T-2)\ 275}{0.4} + (T + 38)\ \frac{280}{2.4} + \frac{275}{3.8}$$

$$= 876T + 5807 \text{ (watts)}$$

INSTANTANEOUS INFILTRATION LOSS = 0.335 x volume x temperature difference X number of air changes per hour (watts)

Building volume = $950m^3$

Assume air change rate of 1.5 because of sliding wall sections

Therefore: **Instantaneous infiltration heat loss**
= 0.335 X 950 X (T + 38) X 1.5

= 477 T + 18,140 watts

Therefore: **Total instantaneous heat loss** = 1353 T + 23,947 watts

Assuming that this is equal to the heat recovered from the generators

1353 T + 23,947 = 25,000

Therefore T = 1°C

The observed temperatures were 10°C in the workshop, 18°C in the generator room and -5°C in the garage.

APPENIDX K

ESTIMATION OF WIND TURBINE ENERGY CONTRIBUTION

APPENDIX K

ESTIMATION OF WIND TURBINE ENERGY CONTRIBUTION

The energy exerted on a wind turbine at a given windspeed V is 1/2 mV^2, where m is the mass of the "parcel" of air intercepted by a wind turbine. The mass m is equal to the volume of the parcel of air times its density g, and over a time period t, the volume of air is equal to A_tVg, where A_t is the area of the rotor. Therefore:

$$\text{Energy} = \tfrac{1}{2}\, A_t t g V^3$$

Power is the rate of energy conversion, therefore:

$$\text{Power} = \tfrac{1}{2}\, A_t g V^3$$

Because the wind turbine actually reduces the wind speed as it passes the rotors, the maximum power obtainable from the wind is equal to constant 0.59 times the theoretical power available. There are also losses because of rotor design and friction losses in gearboxes etc. Actual wind turbine power output is therefore equal to:

$$0.59\ (\text{Turbine efficiency}) \times \tfrac{1}{2}\, A_t g V^3$$

The factor 0.59 (turbine efficiency) is usually called the coefficient of performance for the turbine C_p.

Using an average air density g of 1.22 Kg/m^3, the available windpower at a given windspeed V m/s is therefore 0.61 $C_p A_t V^3$ watts, where A_t is in m^2.

To determine the annual output from a wind turbine it is necesary to know the velocity distribution (velocity vs fraction of the year wind is above that velocity) at the given location. Because a wind turbine has a finite cut-in speed and cut out speed, it will only contribute power when the wind is between these speeds.

Annual operating time T(hrs)
= 8670 (Fraction of time wind is above cut in speed
- Fraction of time wind is below cut-out speed)

The annual power contribution is therefore the sum of all contributions while the wind is between the cut-in and cut-out speeds V_1 and V_2, or

$$\text{Annual energy contribution} = \int_1^2 0.61 C_p A_t V^3 dt$$

This may be approximated to:

$$\text{Annual energy contribution} = 0.61 C_p A_t V^2{}_m \int_1^2 V dt$$

where V_m is the median windspeed during the turbine operation.

Now $\int_1^2 V dt$ is the area A_w under the velocity distribution curve between V_1 and V_2, times the annual operating time T; therefore:

Annual energy contribution (watt hrs/yr.)

$$= 0.61 C_p A_t Vm^2 \, A_w T$$

APPENDIX L

SLATE FALLS COMMUNICATIONS POWER SYSTEM ENERGY AUDIT CALCULATIONS

APPENDIX L

SLATE FALLS COMMUNICATIONS POWER SYSTEM
ENERGY AUDIT CALCULATIONS

Generator set:	Ball 7.5 kW
Engines (2):	Lister ST-2, 4 cylinder, naturally aspirated, air cooled, 12.6 HP
Generators (2):	Aircraft Appliances & Equipment, model G1260-505, rated 15 KVA, 15 kW, 1.0 power factor, 125/62.5 amps, 120/240 volt, 60 Hz.

Measured load at 11:00 am. during site visit was 4.1 kW (4.1 KVA)

Assuming 80% generator efficiency because of low load:

$$\text{Engine shaft HP} = \frac{4.1}{0.746 \times 0.80}$$

$$= 6.85 \text{ BHP}$$

The engine is therefore loaded at 55% of capacity.

Assuming a fuel consumption of 0.46 lbs/BHP/hour because of low load:

$$\text{Engine fuel consumption} = 6.85 \times 0.46$$

$$= 3.15 \text{ lbs/hr.}$$

$$= 1.7 \text{ litres/hr.}$$

At a fuel heat value of 10.6 kWh/litre then:

Total heat produced = 10.6 X 1.7

= 18 kW

Therefore: Generator set thermal efficiency = 4.1/18

= 23%

With a generator efficiency of 80%

Engine thermal efficiency = 28.5%

Engine losses = 71.5%

Assuming that the average load is equal to the observed load of 4.1:

Annual fuel consumption at 4.1 kW

= 1.7 X 24 X 365

= 14,900 litres/year

At 4.1 kW or 6.85 H.P. this engine is being loaded to only 55% of its capacity, and for an engine running on a continuous basis this is far too low a load, particularly in low ambient temperatures, and will lead to fouling of the injectors and irregular running of the engine. A low load also results in polishing of the cyclinder walls due to lack of pressure to seat the piston rings properly. This applies particularly to constant speed engines. Ultimately the engine will pump lubricating oil into the piston where it will burn and aggrevate the fouling of the injectors which will ultimately lead to engine failure.

APPENDIX M

DESIGN HEAT LOSS CALCULATIONS FOR REMOTE COMMUNICATIONS BUILDINGS IN NORTHERN ONTARIO

APPENDIX M

DESIGN HEAT LOSS CALCULATIONS FOR REMOTE COMMUNICATIONS BUILDINGS IN NORTHERN ONTARIO

Exchange Building

Overall dimensions:

Width:	4.3 m
Length:	6.1 m
Height:	2.4 m
Volume:	63m^3

Walls: Metal stud with 2" white styrofoam insulation and 2" blue styrofoam insulation (metal clad) RSI 3.1 (R18). Area 48 m^2.

Ceiling: Metal with 9" fibreglass insulation (metal clad) RSI 5.2 (R29.5). Area 26 m^2.

Floor: Wood (2x4) joist under wood platform with 2" white styrofoam insulation RSI 1.7 (R10). Area 26 m^2.

Door: Single standard insulated steel RSI 0.7 (R4). Area 2 m^2.

Infiltration (estimated): 0.75 air changes per hour

Design heat load:

$$= \frac{48}{3.1} + \frac{26}{5.2} + \frac{26}{1.7} + \frac{2}{0.7} + (0.35)(63)(0.75)$$

$$= 55 \text{ watts/°C}$$

Satellite/Toll Building

Overall dimensions:

Width:	3.5 m
Length:	4.0 m
Height:	2.4 m
Volume:	33 m^3

Walls: Wood frame with 3½" fibreglass insulation with wood siding RSI 2.4 (R13.6). Area 34 m^2.

Ceiling: Wood frame with 5½" fibreglass insulation RSI 3.8 (R21.6). Area 14 m^2.

Floor: Wood joist under wood platform with 2: white styrofoam insulation RSI 1.7 (R10). Area 14 m^2.

Door: Single standard insulated steel RSI 0.7 (R4). Area 2 m^2.

Infiltration (estimated): 0.75 air changes per hour.

Design Heat Load:

$$= \frac{34}{3.6} + \frac{14}{3.8} + \frac{14}{1.7} + \frac{2}{0.7} + (0.35)(33)(0.75)$$

$$= 37.5 \text{ watts/°C}$$

APPENDIX N

MECHRON ENERGY LIMITED SERIES 2000 CYCLE CHARGE DIESEL GENERATING SYSTEM

APPENDIX N

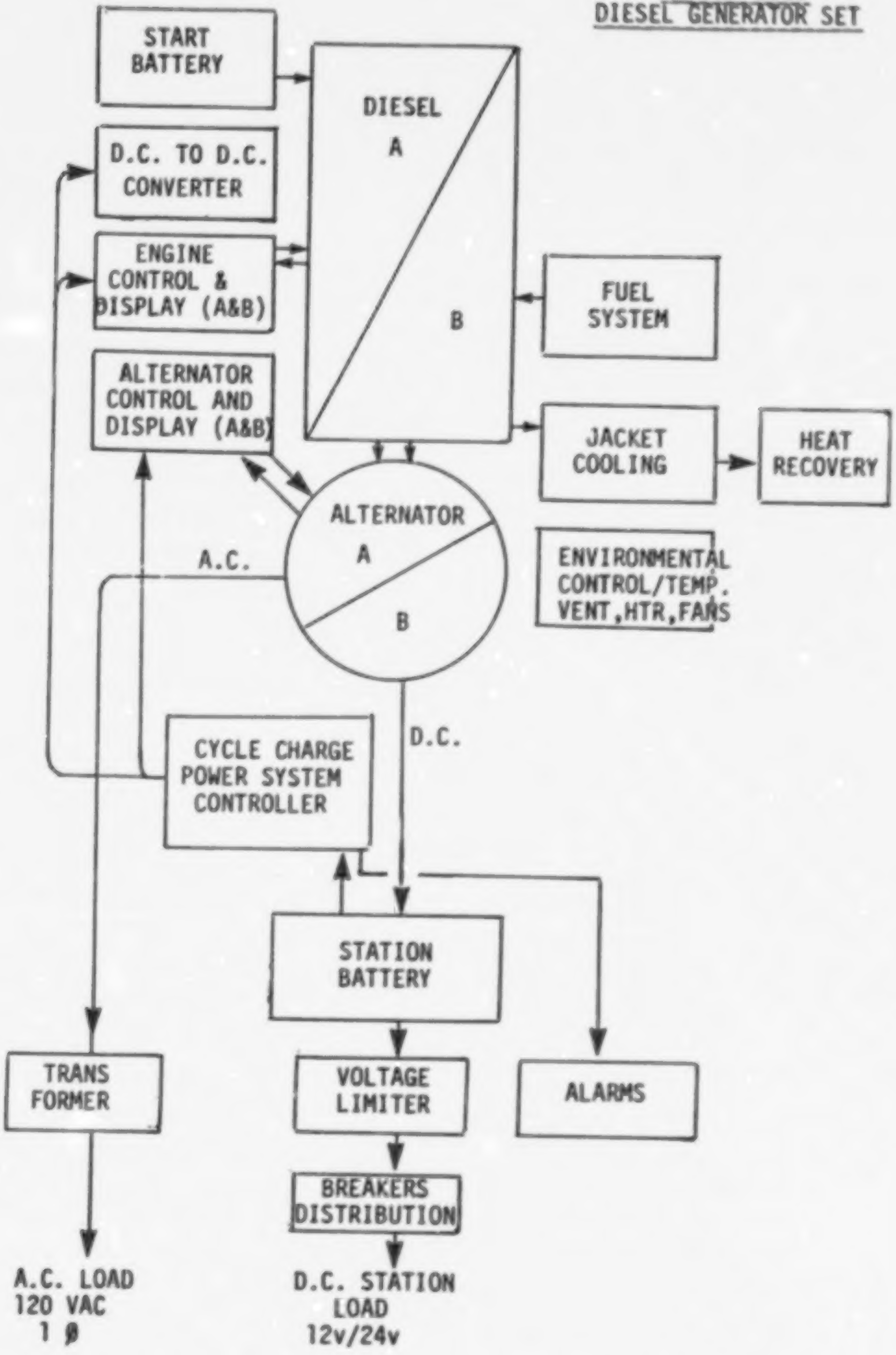
MECHRON ENERGY LIMITED SERIES 2000 CYCLE CHARGE DIESEL GENERATING SYSTEM

This Appendix includes the following information regarding the Series 2000 Cycle Charge system.

- Functional Block Diagram for Mechron Series 2000 Cycle Charge System (Figure 6.1)
- Mechron Cycle Charge Prime Power Systems Brochure

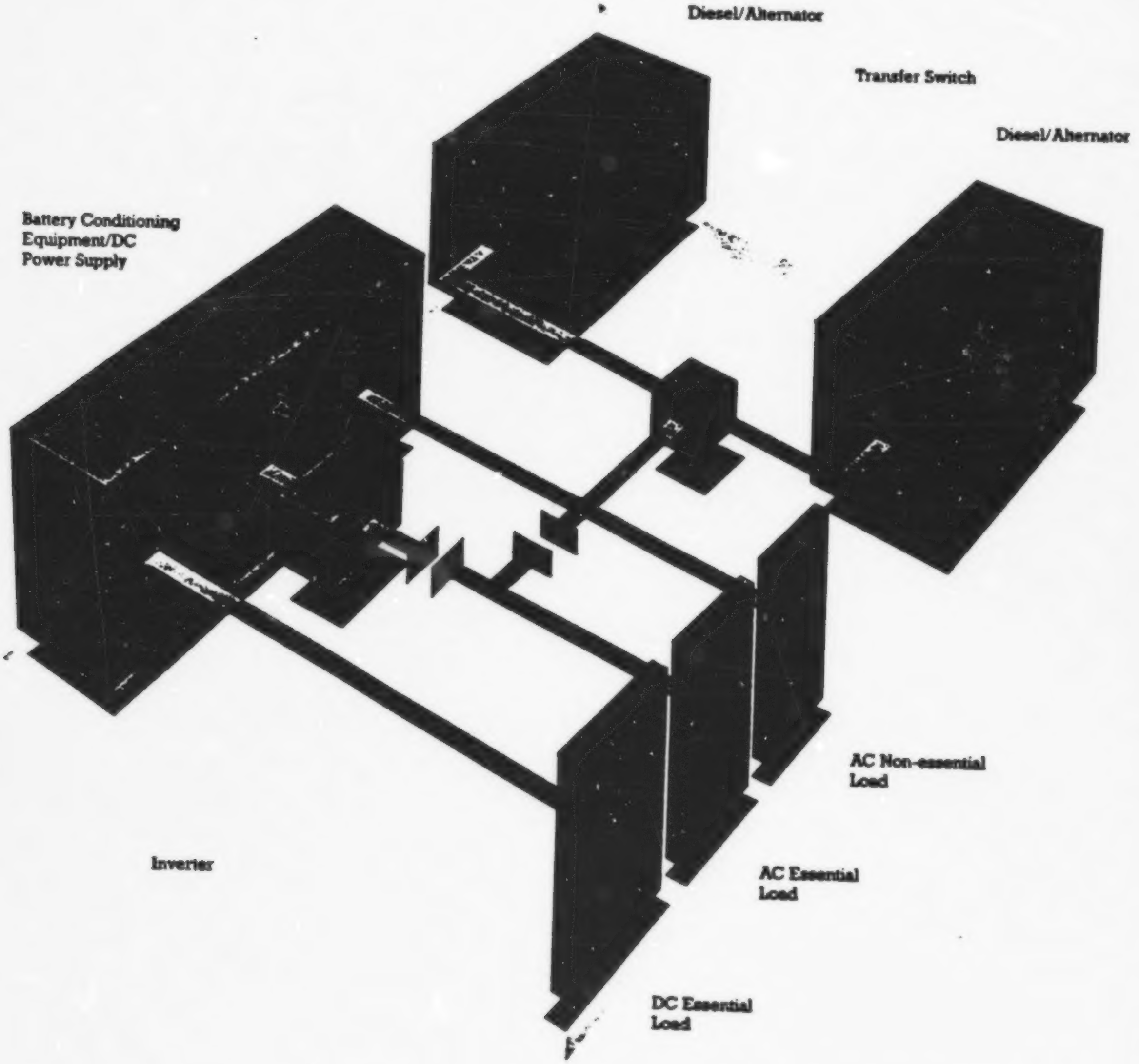
- Recommended Engine for a 5kW Series 2000 unit.

FIGURE 6.1
FUNCTIONAL BLOCK DIAGRAM
MECHRON ENERGY LTD.
CYCLE CHARGE
SERIES 2000
DIESEL GENERATOR SET


START BATTERY
DIESEL
A
B
D.C. TO D.C. CONVERTER
ENGINE CONTROL & DISPLAY (A&B)
FUEL SYSTEM
ALTERNATOR CONTROL AND DISPLAY (A&B)
JACKET COOLING
HEAT RECOVERY
ALTERNATOR
A
B
A.C.
ENVIRONMENTAL CONTROL/TEMP. VENT,HTR,FANS
D.C.
CYCLE CHARGE POWER SYSTEM CONTROLLER
STATION BATTERY
TRANS FORMER
VOLTAGE LIMITER
ALARMS
BREAKERS DISTRIBUTION
A.C. LOAD 120 VAC 1 ø
D.C. STATION LOAD 12v/24v

CYCLE CHARGE
Prime Power Systems

MECHRON


Diesel/Alternator
Transfer Switch
Diesel/Alternator
Battery Conditioning Equipment/DC Power Supply
AC Non-essential Load
Inverter
AC Essential Load
DC Essential Load

An energy efficient prime power supply for remote communications sites and other applications.

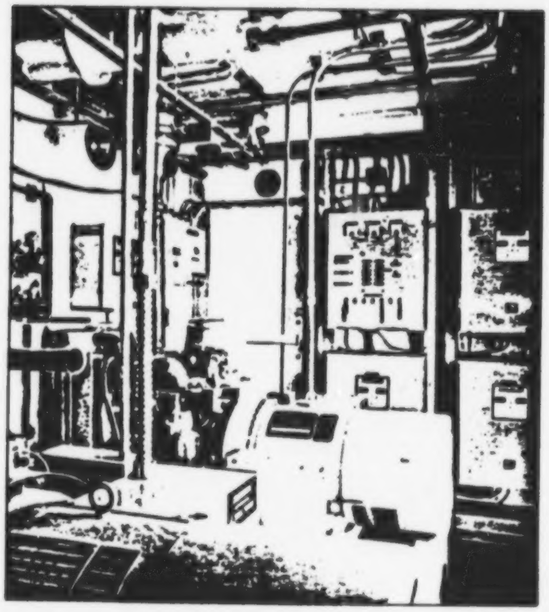
- **Fuel savings of up to 70% will give a rapid return on investment.**
- **Longer life of generator set engines and batteries.**
- **Extended refuelling intervals.**
- **Reduced maintenance requirements.**

Mechron's **CYCLE CHARGE** Prime Power Systems deliver low wattage power for a variety of applications in which A.C. power lines do not exist or would be too expensive to construct. Each **CYCLE CHARGE** system consists of the following components:

- 2 diesel generators, one active with the second in a standby mode
- redundant rectifiers
- large "station" battery bank
- D.C. control and distribution system
- fuel and exhaust system

Depending on your application requirements, the following options are also available:

- exhaust heat recovery system
- low loss ventilation system for cold climates
- battery manifold ventilation system
- system monitoring and control telemetry
- D.C. ventilation system
- D.C. to A.C. inverter
- weatherproof, transportable prepackaged system container



System Applications

Typically, these systems provide all the power requirements for remote telecommunications facilities (i.e., microwave sites), pipeline compressor stations, weather stations, and other low wattage situations. Scaled-up versions also supply the needs of stationary and transit construction camps.

In an isolated communications installation, for example, power is required to meet rectifier demands at full load, cooling, heating and lighting loads, and other environmental loads such as fuel pumps, tower lights, housekeeping, etc. All these requirements can be economically and efficiently handled using **CYCLE CHARGE** systems.

How it Works

The essential equipment loads are connected to the battery bank which is charged by rectifiers connected to the two diesel generator sets.

When the battery voltage discharges to 75% of its initial capacity, one generator set starts and outputs 60 Hz to feed the rectifiers and thereby recharges the battery. Rectifier output is sufficient to minimize the time required to recharge the battery. At least two rectifiers are used to ensure high reliability factors in the system.

Should the preferred generator set fail, the standby set automatically starts and assumes the load. In the unlikely event that both generator sets fail, there would be sufficient reserve in the battery to power the system for at least 24 hours. Battery reserves can be increased or decreased, subject to application requirements.

Along with low battery voltage, the diesel generators will also start under the following conditions:

- high or low building temperatures
- remotely, via radio command
- manually, should service personnel require A.C. power

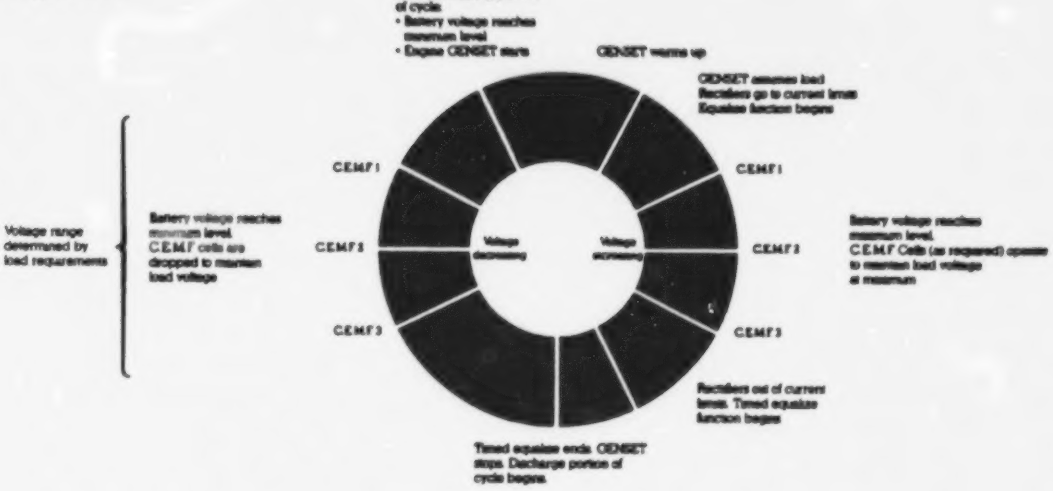
To limit the load voltage fluctuations, all D.C. power plants are equipped with counter electromotive force (C.E.M.F.) cells.

CYCLE CHARGE vs Continuous Prime Power

When planning for a remote power system, it is necessary to include a generator set large enough to meet the worst case load. For a variety of factors, actual operating loads can vary from 10% to 100%. As diesel engines only work at their most efficient level at 60% to 90% of capacity, standard prime power arrangements are not always efficient. In order to reduce the frequency of diesel engine overhauls resulting from this intermittent activity, it is necessary to add artificial loads during periods of light loading to provide complete fuel combustion which, in turn, increases fuel consumption and associated costs.

With the **CYCLE CHARGE** system, the diesel engine always operates in its most efficient range, and only needs to run 25% or less of the time, resulting in lower fuel consumption and engine maintenance.

The Cycle Charge Sequence


Assumed starting position of cycle
• Battery voltage reaches minimum level
• Engine GENSET starts
GENSET warms up
GENSET assumes load
Rectifiers go to current limits
Equalize function begins
CEMF 1
Battery voltage reaches maximum level.
CEMF Cells (as required) operate to maintain load voltage at maximum
CEMF 2
CEMF 3
Rectifiers out of current limits. Timed equalize function begins
Timed equalize ends. GENSET stops. Discharge portion of cycle begins.
CEMF 3
CEMF 2
CEMF 1
Battery voltage reaches minimum level.
CEMF cells are dropped to maintain load voltage
Voltage range determined by load requirements
Voltage decreasing
Voltage increasing

CYCLE CHARGE System Benefits

High Reliability

With Mechron's **CYCLE CHARGE** system, A.C. power is always available on demand for heating & cooling equipment, housekeeping, and similar needs. The use of a second diesel generating set in "standby" mode and backup rectifiers assures high power reliability through redundancy. In the unlikely situation where the system fails, the battery banks can supply the necessary load for 24 hours. The overall system is so efficient that major diesel overhauls are not generally necessary during the first 10 years of use.

Efficiency Plus Low Maintenance

Fuel and maintenance costs can be reduced by as much as 70% over conventional prime power systems. During run cycles, the diesel operates only at efficient load levels (80% load). Depending on climatic and other site conditions, the system can be designed to operate as little as 25% of the time, thus saving fuel and extending machine life. The accompanying chart outlines the remarkably low fuel consumption of the diesels in a variety of system configurations. The fuel tank can be sized so that refuelling is required only *once* or *twice* a year.

As well, because the batteries never experience discharges in a deep cycle condition, their operating lifespan increases from the usual 3 years to between 7 and 10 years—a considerable cost savings!

Ventilation is not required during the discharge cycle, and the generator set or power room is self-ventilating by the engines themselves during the engine run cycle. This eliminates the need for costly venting installations. Battery banks are connected through a common manifold to the exterior of the building to eliminate hydrogen gas buildup.

In cold climates, a heat exchanger, storage and recovery system is provided. During diesel operation, the engine exhaust waste heat is stored in a tank of ethylene glycol. The stored heat is circulated to maintain a suitable climate for the equipment and facilitate diesel re-starts. No other ancillary heating systems are needed.

For your maintenance personnel who are already acquainted with prime power diesel generator systems, no special training is required. In fact, typical **CYCLE CHARGE** systems can be installed and operating within two days of site delivery!

Total Flexibility

Various options can be incorporated into the **CYCLE CHARGE** system to meet your specific needs. Varying D.C. loads, especially load increases, can be accommodated with minimal or no changes in system cost or equipment. Telemetry monitoring and alarm systems can also be installed for remote operation and maintenance of the system.

Mechron's **CYCLE CHARGE** systems can also be used in conjunction with solar arrays or wind generators, further reducing engine running time and fuel costs.

System components can be assembled in your existing building, or can be factory assembled in our reliable prepackaged system containers. Where new systems are planned, we recommend our prepackaged method for these reasons:

- transportation to site is accomplished by either train, boat, truck, Hercules aircraft or helicopter.
- weatherproof enclosure provides excellent temperature controlled environment for radio equipment, employee survival quarters, and battery and power equipment.
- complete factory assembly ensures strict quality control. Every component is factory tested, which permits field installation in as little as two days.
- construction costs can be fixed without any reserve funds being set aside for unknown field costs associated with erecting a building and installing equipment on site. Foundation costs are minimized as our prepackaged systems can be installed on a concrete pad, permanent foundations, treated timbers, or level terrain.

When ordered in its pre packaged version, the **CYCLE CHARGE** system comes complete with its own fuel system, ventilation apparatus, etc. If the unit is to be installed in an existing building, all ancillary equipment is available at your request.

Typical Operating Data

System Voltage	24	24	24	24	24	48	48	48	48	48
Load in Watts	100	300	500	700	900	200	400	600	800	1000
Engine Hours Yearly	219	458	728	1072	1378	292	895	915	1222	1529
Yearly Fuel Consumption										
Litres	664	2082	3309	4873	6264	1327	4069	4160	5555	6950
Imperial Gal	146	458	728	1072	1378	292	895	915	1222	1529

About Mechron

Mechron is Canada's leading energy systems engineering company providing energy-efficient electrical power generating systems for more than 5000 critical applications installed around the world.

Mechron products and systems include:

Fuel-driven Systems:
- Standby Power
- Primary Power
- Rotary Ups
- Cycle-Charge
- Thermoelectric Generator

System Controls:
- Power
- Process

Renewable Energy Systems:
- Photo Voltaic & Hybrid Systems
- P.V. Panels & Cells
- Wind/Water Control Systems

Transportable Containers/Enclosures:

D.C. Systems
- Battery Charging Rectifiers
- D.C. Distribution Systems

Services:
- Engineering
- Installation and Maintenance

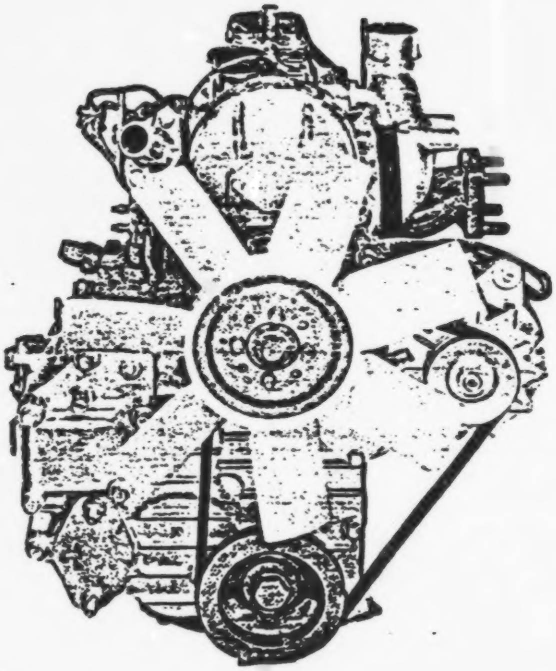
For further information on any products mentioned above, please contact the Marketing Department at

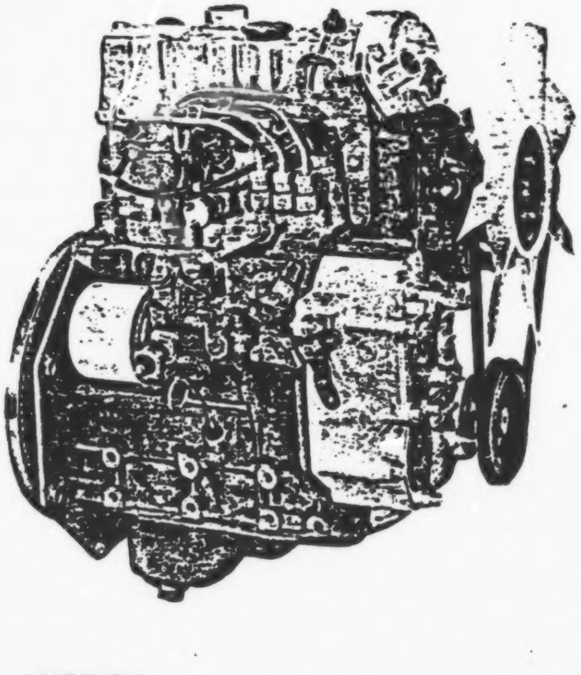
MECHRON

Mechron Energy Ltd.
2437 Kaladar Avenue,
Ottawa, Ontario K1V 8B9
Telephone: (613) 733-3855

Printed in Canada

ISUZU K-SERIES
Small OHC Diesel Engines





ISUZU DIESEL OF NORTH AMERICA
41169 Vincenti Court • Novi, Michigan 48050-2689 • (313) 474-8000

ENGINE SPECIFICATIONS

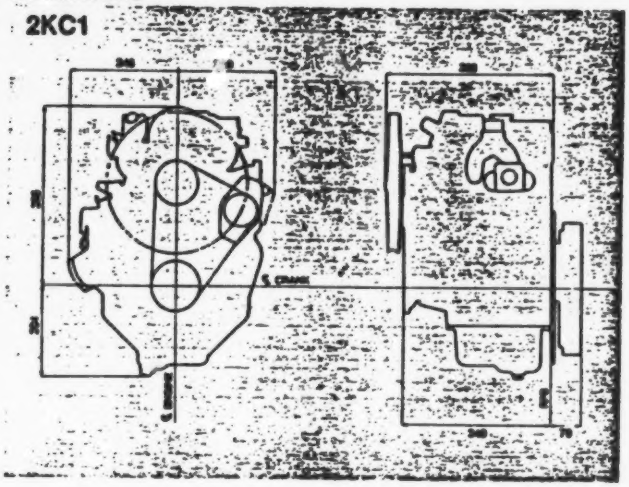
Acc. to DIN

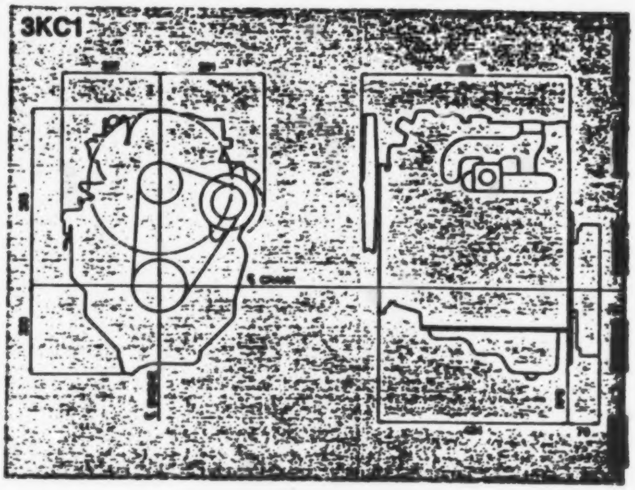
MODEL	OUTPUT kW (PS)/MIN		MAX TORQUE Nm (Kgfm)/MIN	TYPE			BORE X STROKE	DISPLACEMENT	DRY WEIGHT
	INTERMITTENT	CONTINUOUS		CYCLE	COMBUSTION	CYL. NO.	MM	CU CM	Kg
2KA1	7.6 (10)/3000	6.8 (9.0)/3000	26.5 (2.7)/2000	4	SC	2 - IL	70 x 70	539	79
2KB1	8.7 (12)/3000	7.8(10.6)/3000	29.4 (3.0)/2000	4	SC	2 - IL	70 x 76	584	82
2KC1(QT15)	10.3 (14)/3000	9.2(12.5)/3000	37.3 (3.8)/2000	4	SC	2 - IL	74 x 76	653	82
3KA1	12.5 (17)/3000	11.2(15.3)/3000	42.1 (4.3)/2000	4	SC	3 - IL	70 x 70	808	100
3KB1	13.7 (19)/3000	12.3(17.7)/3000	47 (4.8)/2000	4	SC	3 - IL	70 x 76	877	103
3KC1(QT23)	16.2 (22)/3000	14.7 (20) /3000	59 (6) /2000	4	SC	3 - IL	74 x 76	980	103

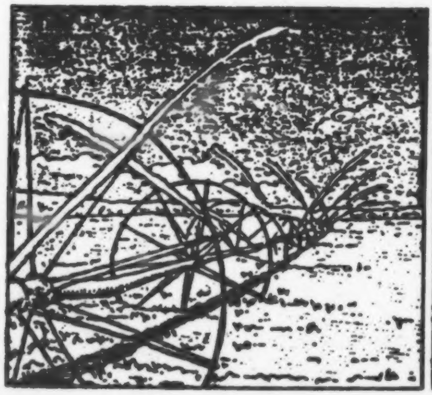
SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

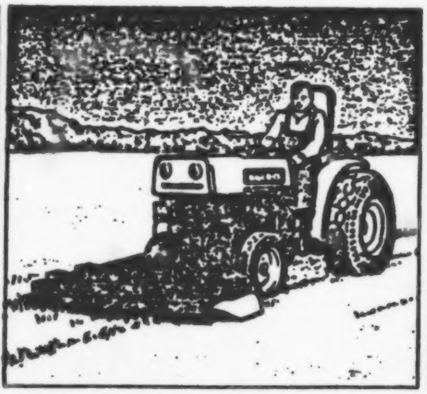
PRODUCTION TOLERANCE 0 - 5% *W/O STARTER AND ALTERNATOR

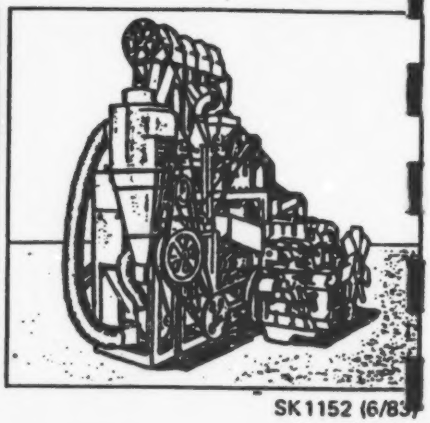
DIMENSIONS





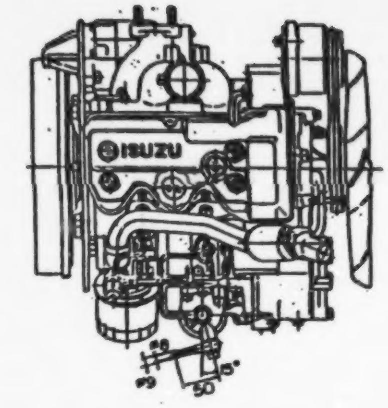


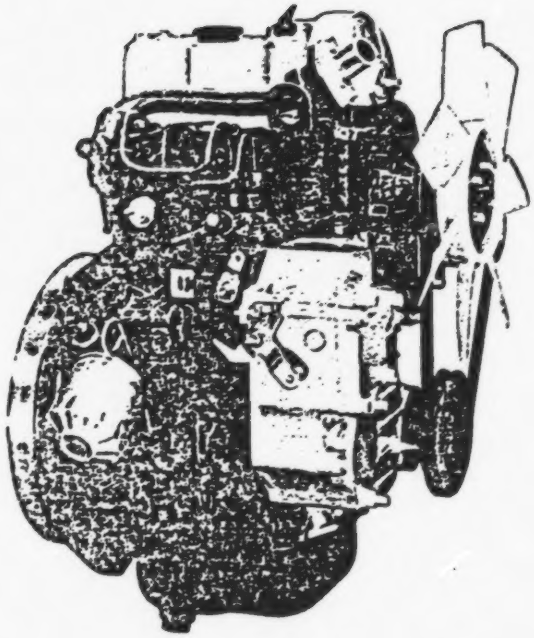


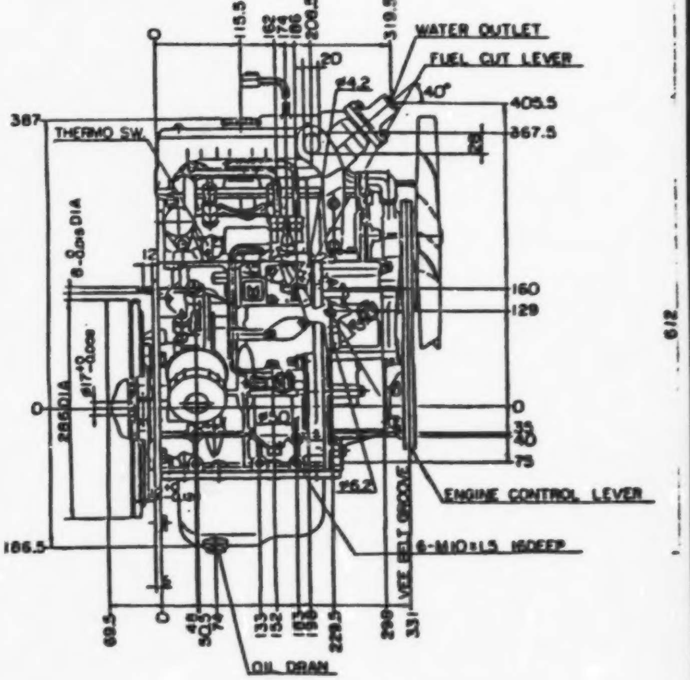


SK1152 (6/83)
Litho in U.S.A.

2KC1 (QT-15)


ISUZU
48
39
50
15°




0
115.5
162
174
186
208.5
319.5
WATER OUTLET
FUEL CUT LEVER
20
ø4.2
40°
405.5
387
THERMO SW.
367.5
38
8-8 DIA
12
160
129
612
ø117
285 DIA
0
0
35
40
75
ø6.2
ENGINE CONTROL LEVER
VEE BELT GROOVE
186.5
6-M10×1.5 16DEEP
69.5
0
41.5
50.5
74
133
152
183
198
229.5
290
331
OIL DRAN

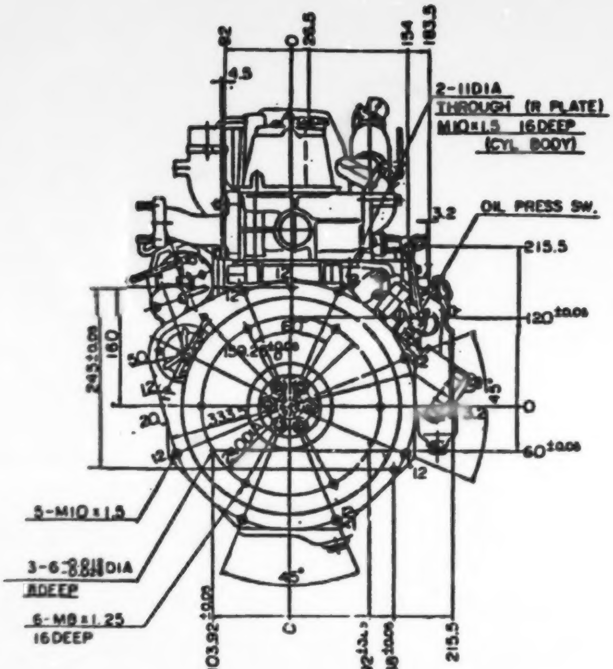
SAE J(1349) INDUSTRIAL RATINGS

GROSS INTERMITTENT. .	15.5 BHP/3000 RPM
*NET INTERMITTENT.	15 BHP/3000 RPM
*NET CONTINUOUS	13.5 BHP/3000 RPM
MAX TORQUE.	30 LB-FT/2000 RPM

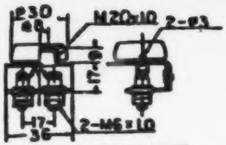
*Includes Fan

FOR ADDITIONAL COPIES ASK FOR
PUBLICATION NO. SK-1159

2KC1 DIESEL ENGINE (QT-15)

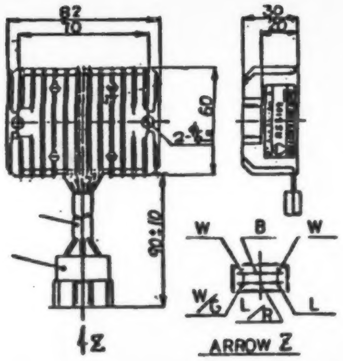


82
25.5
134
183.5
4.5
2-11DIA THROUGH (R PLATE)
M10×1.5 16DEEP (CYL BODY)
3.2
OIL PRESS SW.
215.5
120±0.05
245±0.05
160
50
12
20
0
60±0.05
5-M10×1.5
3-6 DIA 8DEEP
6-M8×1.25 16DEEP
45°
103.92±0.05
103.92±0.05
138±0.05
215.5



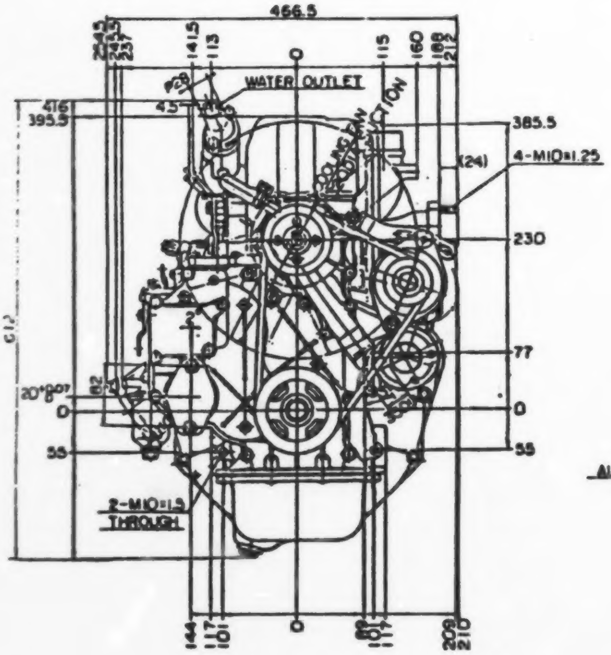
φ30
M20×1.0
2-φ3
17
36
2-M6×1.0

CONTROL RESISTANCE

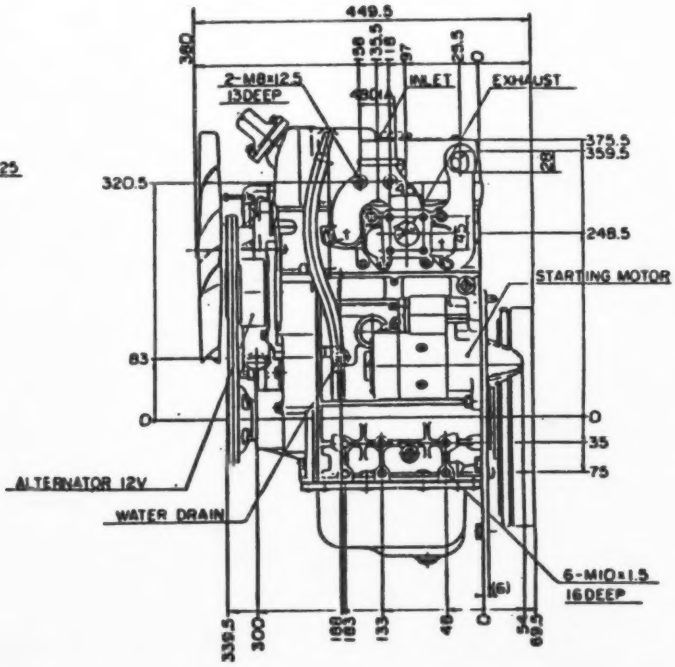


82
70
30
20
60
2-φ
90±10
Z
W
B
W
W/G
L
R
L
ARROW Z

REGULATOR 581251-0140



466.5
141.5
113
115
160
188
212
416
395.5
φ28
4.5
WATER OUTLET
385.5
(24)
4-M10×1.25
230
77
20
0
55
0
55
2-M10×1.5 THROUGH
144
117
101
0
101
117
209
210



449.5
380
158
135.5
118
97
25.5
0
2-M8×1.25 13DEEP
INLET
EXHAUST
375.5
359.5
320.5
248.5
STARTING MOTOR
83
0
0
35
75
ALTERNATOR 12V
WATER DRAIN
6-M10×1.5 16DEEP
339.5
300
188
183
133
46
0
54
69.5

ISUZU DIESEL OF NORTH AMERICA

NOVI, MICHIGAN

SK – .65 - 300 - 1159 SHEET 1 of 1

JUNE 1983

(QT-15) 2KC1 SPECIFICATIONS

1. General

Type	Four cycle, water-cooled, vertical in-line, overhead cam, swirl chamber type.
Piston displacement	653 cm^3
Cyl. nos-bore x stroke	2-74 x 76 mm
Performance (According to DIN 6270)	
Intermittent rating	10.3 kW (14 PS)/3,000 min^{-1}
Countinuous rating	9.2 kW (12.5 PS)/3,000 min^{-1}
Max. Torque	37.3 Nm (3.8 kgfm)/2,000 min^{-1}
Engine rotation direction	Counter clockwise viewed from flywheel.
Engine starting method	By starter motor
Engine stop method	By fuel cut lever
Compression ratio	23 to 1
Dimensions (L x W x H)	450 x 466 x 600 mm
Air intake system	Naturally aspirated
Firing order	1-2
Fuel used	Diesel fuel ASTM2D
Polarity and voltage of electical system	Negative grounding system, 12V
Dry weight	82 kg without starter and alternator
Lubrication oil capacity	2.7 lit.
Coolant capacity	1.5 lit., engine only.

2. Cylinder body

Type	Monoblock cast, three bearings support type body and cast integral crank case. Lub. oil gallery is contained within body assembly.

3. Cylinder head

Type	Monoblock cast, overhead cam type, containing swirl chamber, glow plugs and injection nozzles within head assembly.
Head cover	Of aluminum alloy.
Inlet manifold	Of aluminum alloy, center upward inlet type on LH side. Attachment to the head by studs fixed together with exhaust manifold.
Exhaust manifold	Of Cast iron, center sideward outlet type, connecting frange, and studs on LH side.

4. Crankshaft

Type	Of ductile cast iron and high-frequency hardend pins and journals, integral counter weight. Dinamically balanced.
Flywheel	8" single plate spring loaded clutch type.
Main bearing	Steel backed, aluminum alloy metal.
Nominal diameter	
Pin	43 mm
Journal	52 mm
Crankshaft pully	Single vee belt groove w/SAE 'TYPE I' PTO.

5. Camshaft

Type	Cast alloy iron, three bearings support.
Drive	Driven by timing chain from front.

6. Connecting rod

Type	Drop forged I-beam section type.
Large end bearing	Steel backed, aluminum alloy metal, replaceable type.

7. Pistons

Type	Slipper skirt, trunk type, of Lo-ex aluminum alloy. Two compression ring grooves and one oil control ring groove.
Piston pin and retention method	Tubular full floating, by snap ring.
Compression rings	Chromium plated, barrel face top ring. Taper face 2nd ring.
Oil control ring	Dual scraper type with coil expander.

8. Valve mechanism

Type	Direct-acting overhead cam.
Valve lash	0.25 mm (0.01") for inlet and exhaust when engine cool.
Inlet valve	Of heat resisting steel poppet type.
Exhaust valve	Of heat resisting alloy poppet type.
Diameter of valve head	Inlet 35 mm, Exhaust 31 mm
Valve timing	
Inlet	Open 8° (BTDC) Close 34° (ABDC)
Exhaust	Open 51° (BBDC) Close 9° (ATDC)

9. Cooling system

Type	By pressurised water forced circulation.
Water pump	Centrifugal, vane type, by vee belt driven from crankshaft pully.
Speed ratio	Pump to crankshaft pully 1.228 to 1 or 1.119 to 1
Thermostat	Wax pellet type
Opening temperature	76.5°C (170°F)
Water circulation	Pump to body to head
Cooling fan	320 mm (12.6") dia., seven blades sucker type.

10. Lubrication system

Type	Full forced pressure feed, type.
Oil pump	Trochoid type, herical gear driven from cam shaft end of injection pump.
Oil pan	Of pressed steel sheet, full sump type.
Oil filter	Full flow, paper element cartridge type on RH.

11. Fuel system

Type	By plunger and nozzle, high pressure solid injection type.
Injection pump	Diesel Kiki make, in-line Bosch PFR type injection pump.
Injection nozzle	Diesel Kiki make, Bosch throttle type, mounted by flange type nozzle holder.
Injection timing and pressure	12 degree BTDC, 120 kg/squ.cm (1,700 psi)
Fuel filter	Paper element type.

12. Electrical system

Starting aid	Sheathed type glow plugs rated voltage and current 10.5V, 6.5A.
Starter	12V-0.8kW, magnetically actuated
Alternator/regurator	12V-7A
Recommended battery capacity	65 AH

TECHNICAL DATA
2KC1 (QT-15)

General

Number of cylinder		2
Displacement	cm³	653
Moment of inertia GD²	kgm²	
Speed droop		
Permanent for genset	%	5
Idle rpm	min⁻¹	800 ± 50
No load max rpm	min⁻¹	3300

Cooling system

Water discharge volume of water pump at 80°C coolant temperature	lit/min⁻¹	55/3000
Thermostat		
Opening temperature	°C	76.5
Fully opened temperature	°C	90
Top Tank temperature		
Normal	°C	80 ~ 85
Max. allowable	°C	95
Min. allowable radiator cap pressure	kg/cm² (psi)	0.5 (7)
Heat rejection	MJ/min	0.608/3000, 0.717/3600
Cooling water capacity (engine only)	lit.	1.5

Air intake system

Inlet restriction		Normal Duty	Medium Duty	Heavy Duty
Air cleaner				
Dry type (Element Only)	mmH2O	250	–	–
Dry type (With Precleaner)	mmH2O	300	250	–
Heavy duty dry type (Precleaner and Safety Element)	mmH2O	380	300	250
Max. allowable inlet restriction with dirty air filter element	mmH2O	635	635	635
Air flow	m³/min	1.34/3000,	1.8/3600	

5000 ft altitude — 86%

100°F

Exhaust system

Exh. back pressure		
Normal	mmHg	75
Max. allowable	mmHg	150
Exh. pipe		
Min. allowable internal diameter	mm	32
Exh. temperature	°C	500/3000, 530/3600
Exh. gas flow	m³/min	2.2/3000, 2.7/3600

Lubrication system

Standard oil pan capacity	lit.	Max. 2.7, Min. 1.7
Oil pressure at 80°C oil temperature	kg/cm²	1.5 ~ 2/idle, 3/1600, 4/3000, 4.5/3600
Angularity limits of std oil pan	deg.	Front up 30, Front down 30, Side to side 30

Fuel system

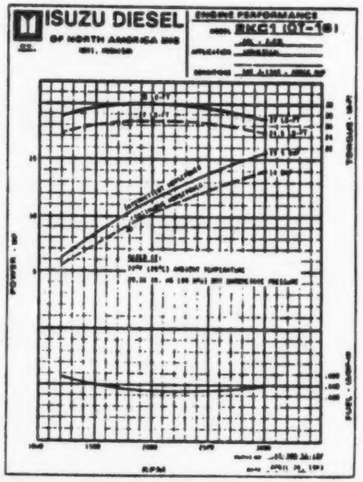
Feed pump suction head	m	1
Fuel pipe min. allowable internal diameter	mm	8

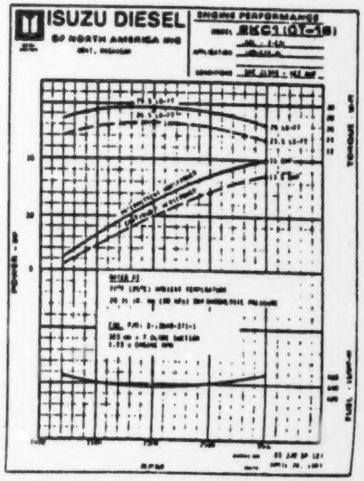
Electrical system

Max. allowable resistance of starting circuit with 12V starter	mΩ	1
Recommended battery capacity	V – AH	12 – 65

Power take off

Front P.T.O.	kgfm	3.8 kgfm (in-line application)





APPENDIX O

EFFECTIVENESS OF GLYCOL STORAGE TANK HEAT RECOVERY/COOLING SYSTEM WITH A CYCLE CHARGE DIESEL GENERATING SYSTEM

APPENDIX O

EFFECTIVENESS OF GLYCOL STORAGE TANK HEAT RECOVERY/COOLING SYSTEM WITH A CYCLE CHARGE DIESEL GENERATING SYSTEM

Heating

Heat produced by 5 kW series 2000 generator set is approximately 0.8 times electrical output.

ie. Heat produced = 4 kW (13,650 Btu/hr)

Heat capacity of a 100 gallon (0.45 m^3) tank of 50/50 glycol/water at 60°C (density 1.04 kg/m^3, specific heat 3.4 MJ/kg°C)

$$= (3.4)(1.04)(0.45) \text{ MJ/°C}$$

$$= 1.6 \text{ MJ/°C}$$

$$= 0.44 \text{ kWh/°C}$$

Therefore number of hours for the engine to heat up 100 gallons of 50/50 glycol from 30°C to 90°C

$$= \frac{0.44 \times 60}{4}$$

$$= 6.6 \text{ hrs.}$$

Cooling

The 100 gallon uninsulated tank of 50/50 glycol water will cool by a combination of natural convection and radiation. With cooling air circulating through the tank enclosure at a maximum of 25°C and assuming the enclosure to have an emissivity of 1.0, the combined convection and radiation losses from the tank when it is at temperature T°C

$$= h_c A (T-25) + seA((T+273)^4 - (298^4)) \quad \text{(watts)}$$

where h_c = convection heat transfer coefficient (watts/m^2°C)

A = tank surface area

s = Stephan Boltzman constant (5.67×10^{-8} W/m^2°K)

e = emissivity of tank

Assuming tank dimensions are 0.7m diameter by 1.2m height, the surface area for convection and radiation $A = 2.6\ m^2$. The emissivity of the painted metal tank surface e may be assumed to be approximately 0.6. The convection heat transfer coefficient is a function of temperature and the height of the tank.

$$h_c = 0.29 \left(\frac{\Delta T}{L}\right)^{\frac{1}{4}} \text{ Btu/hr ft}^{2}\text{°F}$$

$$= 1.65 \left(\frac{T-25}{2.19}\right)^{\frac{1}{4}} \text{ watts/m}^{2}\text{°C}$$

Combined heat loss from the tank at temperature T°C is therefore given by:

$$4.3 \left(\frac{T-25}{2.19}\right)^{\frac{1}{4}} (T-25) + 8.84 \times 10^{-8}((T+273)^4 - 298^4) \quad \text{(watts)}$$

At T = 60°C Heat loss = 300 + 390

= 690 watts

Therefore number of hours for the tank to cool from 90 to 30°C (at an average temperature of 60°C) when the outside temperature is 25°C.

$$= \frac{0.44 \times 60}{0.69}$$

= 38 hours

Therefore maximum percent engine running time for the glycol tank to provide adequate cooling when the ambient air temperature is 25°C is 6.6/(6.6 + 38) = 15%. Experience in Newfoundland shows that in summer when these maximum ambient temperatures occur, they are experienced for only a short time and a 15% running time is quite adequate to maintain battery charge during these periods.

APPENDIX P

METHOD USED TO CALCULATE MONTHLY ENERGY SAVINGS FROM USING A PHOTOVOLTAIC ARRAY WITH A DIESEL GENERATING SET THAT HAS JACKET HEAT RECOVERY

APPENDIX P

METHOD USED TO CALCULATE MONTHLY ENERGY SAVINGS FROM USING A PHOTOVOLTAIC ARRAY WITH A DIESEL GENERATING SET THAT HAS JACKET HEAT RECOVERY

Energy Balance (Heating):

Electrical output from diesel generator (heating)
= Base load of communictions equipment
- Solar contribution + Heating Load
- Waste heat contribution - Heat from communications equipment

$$D = B - e_s A\ H_m + X - (e_h/e_d)D - Bf$$

or
$$D = \frac{1}{1+e_h/e_d} \quad B(1-f) - e_s\ AH_m + X$$

where D = diesel generator electrical output (MJ/mo)

B = base load of communications equipment, tower lights etc. (MJ/mo)

X = radio room heating load (MJ/mo)

e_h = fraction of fuel energy recoverable as jacket waste heat

e_d = electrical efficiency of diesel engine/generator

f = fraction of base load energy (B) converted into heat in radio room

H_m = monthly average solar radiation on PV array (MJ/m^2)

The amount of jacket waste heat and radio room heat actually used can never be greater than the heating load X, therefore the above equation only holds if:

$$\left(\frac{e_h}{e_d}\right)D + Bf \leq X$$

$$\text{or } \left(\frac{e_h}{e_d} + f\right)B - \frac{e_h e_s}{e_d} AH_m \leq X$$

In all other situations there will be no waste heat contribution, and the diesel generator output is given simply by:

$$D = B - e_s\ A\ H_m$$

The actual savings from using the PV array will therefore be as follows:

$$\text{If } \left(\frac{e_h}{e_d} + f\right)B - \frac{e_h e_s}{e_d} AH_m \leq X$$

$$\text{Savings} = \left(\frac{e_s}{1+e_h/e_d}\right)AH_m \quad \text{(MJ/mo)}$$

$$\text{If } \left(\frac{e_h}{e_d} + f\right)B - \frac{e_h e_s}{e_d} AH_m > X$$

$$\text{Savings} = e_s\ AH_m \text{ (MJ/mo)}$$

Energy Balance (Cooling):

Electrical output from diesel generator (cooling)

= Base load of communications equipment

- Solar contribution

+ Cooling load

$$D = B - e_s AH_m + Bg - Y$$

$$\text{or } D = B(1+g) - e_s AH_m - Y$$

where:

g = fraction of base load required to be removed by cooling from radio room

Y = radio room natural cooling contribution (positive) or load (negative) (MJ/mo)

The savings from using the PV array will therefore be as follows:

$$\text{Savings} = e_s AH_m \text{ (MJ/mo)}$$

Example:

B = 3425 MJ/mo (1300 watts)

f = 0.5

A = $45 m^2$

$e_d = 0.33$

$e_h = 0.27$

X = 4.75 MJ/Deg. day

Degree Days = 655/mo

Hm = 633 $MJ/m^2/mo$

$e_s = 0.07$

$$\left(\frac{e_h}{e_d} + f\right) B - \frac{e_h e_s}{e_d} AH_m = 4520 - 1630$$

$$= 2890 \text{ MJ/mo}$$

$$X = 4.75 \times 655$$

$$= 3110 \text{ MJ/mo}$$

Because 2890 is less than 3100:

$$\text{Savings} = \left(\frac{e_s}{1 + {}^{e}h/ed}\right) AH_m$$

$$= 1100 \text{ MJ/mo}$$

APPENDIX Q

BELL CANADA EXPENDITURES AT MTC REMOTE COMMUNICATIONS SITES: 1981 THROUGH 1983

1981 DIESEL COSTS - YEAR

R.J. BALL SITES LOCATION	Diesel Fuel 1981 78CX DOLLARS	LABOUR DOLLARS 1981	ACCOUNTS PAYABLE DOLLARS	MEASURED CONTRACT DOLLARS		TOTAL
Angling Lake	14446	8473	30798	-------		53717
Bearskin Lake	9996	5365	16591	Motor Vehicle	2880	34832
Cat Lake	10527	9806	32500	15		52848
Kingfisher Lake	10496	2470	12270	-------		25236
Muskrat Dam	14112	6384	28930	-------		49426
Ogoki Post	14925	10833	50544	10306	5760	92368
Sachigo Lake	17878	4258	29044	4840		56020
Slate Falls	10161	3336	17096	87		30680
Webequie	1997	537	1660	765		4959
Wunnummin Lake	17722	3199	9607	--------		30528
GRAND TOTAL	122260	54661	229040	16013	8640	430614
Average Total Per Site	12226	5466	22904	1601	864	43061
PHASE 1 MTC MECHRON						
Deer Lake	12315	8849	33888	-----		55052
Kasabonika	16679	7676	40544	5668		70567
Kasabonika	-----	914	1265	-----		2179
McDowell Lake	6976	6744	20052	-----		33772
North Spirit Lake	13515	5975	30425	-----		49915
Poplar Hill	13952	1032	3477	Motor Vehicle	467	18928
GRAND TOTAL	63437	31190	129651	5668	467	230413
Average Total Per Site	10573	5198	21609	945	78	38402

1982 DIESEL COSTS - FIRST HALF

R.J. BALL SITES LOCATION	Diesel Fuel 1982 78CX DOLLARS	LABOUR DOLLARS 1982	A.P. DOLLARS	MEASURED CONT. DOLLARS	M.V. DOLLARS	TOTAL
Angling Lake	8435	5377	10582	-------	------	24394
Bearskin Lake	13075	----	-----	-------	------	13075
Cat Lake	11269	2828	10608	-------	------	24705
Kingfisher Lake	14826	----	-----	-------	------	14826
Muskrat Dam	10624	901	3660	6500	------	21685
Ogoki Post	10500	3445	16524	-------	------	30469
Sachigo Lake	12876	1310	3410	-4490	1200	14306
Slate Falls	9074	2171	8183	510	720	20658
Wunnummin Lake	13054	----	-----	-------	-------	13054
GRAND TOTAL	103733	16032	52967	2520	1920	177172
Average Total Per Site	11526	1781	5885	280	213	19686
PHASE 1 MTC MECHRON						
Deer Lake	7127	5653	14689	------	------	27469
Kasabonika	21853	2657	31002	1080	2880	59472
McDowell Lake	6439	3645	12608	------	------	22692
North Spirit Lake	10732	3869	8799	------	------	23400
Poplar Hill	10442	----	----	------	542	10984
GRAND TOTAL	56593	15824	67098	1080	3422	144017
Average Total Per Site	11319	3165	13420	216	684	28804

1983 DIESEL COSTS - YEAR

R.J. BALL SITES	1983 FUEL DOLLARS	LABOUR DOLLARS 1983	A.P. DOLLARS	MEASURED CONT DOLLARS	M.V. DOLLARS	TOTAL
Angling Lake	11506	9018	9793	-------	-----	30317
Bearskin Lake	8927	----	6137	-------	10710	25774
Cat Lake	9816	896	3697	-------	-----	14409
Kingfisher Lake	8891	4757	10711	-------	5610	29969
Muskrat Dam	7416	1114	5680	2161	340	16711
Ogoki Post	8711	2406	10981	-------	11560	33658
Sachigo Lake	7065	2247	6147	1040	4590	21089
Slate Falls	5136	984	4311	-------	-----	10431
Wunnummin Lake	12166	----	1617	-------	4080	-17863
TOTAL	79634	21422	59074	3201	36890	200221
Average Per Site	8848	2380	6564	356	4099	22247
PHASE 1 MTC MECHRON						
Deer Lake	9869	6757	20913	-------	6290	43829
Kasabonika	13399	2111	6274	2620	1020	25424
NcDowell Lake	9855	6476	16116	-------	3910	36357
North Spirit Lake	8673	7595	19057	-------	3400	38725
Poplar Hill	12278	-----	2273	-------	7843	22394
TOTAL	54074	22939	64633	2620	22463	166729
Average Per Site	10815	4588	12927	524	4493	33347